THE CONCOMITANTS OF SLEEP-DISORDERED BREATHING IN ELDERLY MALES

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Sleep Apnea Syndrome (SAS) is a nocturnal respiratory disorder with demonstrated health, sleep/wake, and cognitive consequences. Patients with SAS experience apneas (pauses in breathing of 10 seconds or more), hypopneas (declines in the amplitude of breathing), and oxygen desaturations while asleep. Recently, it has become apparent that sleep-disordered breathing occurs in subjects who have no prominent health, sleep/wake, or cognitive complaints. In this study, a nonclinical sample selected to display a wide range of sleep-disordered breathing (males in good health above the age of 60) received detailed measurement of their nocturnal respiration, nocturnal oxygen saturation, sleep, health status, and cognitive/neuropsychological skills in an attempt to assess the effects of sleep-disordered breathing in a nonclinical population.

Thirty-nine elderly males with a mean age of 66 years comprised the sample. During an experimental evening they received testing and completed questionnaires before sleeping overnight with their sleep and breathing continuously recorded. Fourteen subjects were recorded on two consecutive nights. Seventy-seven percent of the subjects experienced at least one episode of apnea or hypopnea and 20% experienced more than 5 events per hour. Increasing waking blood pressure was linked to increasing numbers of nocturnal desaturations. Many significant relationships between EEG sleep parameters and respiratory indices were found, indicating that arousals subsequent to desaturations lead to fragmented nocturnal sleep. Increasing numbers of desaturations and apneas significantly predicted increased daytime napping behavior. Lower scores on tests measuring IQ, immediate nonverbal memory, visuo-spatial reasoning/organization, and cognitive flexibility were found to be predicted by increasing desaturation activity. Nocturnal respiratory activity was found to remain stable from the first to the second night in the laboratory.

It is concluded that elderly males who experience multiple nocturnal desaturations are at increased risk of sleep fragmentation, daytime sleepiness, increased waking blood pressure, and negative cognitive/neuropsychological changes. Elderly males with nocturnal desaturation may fall on a continuum with Sleep Apnea Syndrome patients.

CHAPTER ONE
INTRODUCTION

Sleep apneas are respiratory pauses during sleep. Sleep Apnea Syndrome (SAS) is a clinical entity diagnosed primarily on the basis of a laboratory finding of multiple apneas (often numbering in the hundreds across the course of a night of sleep) and secondarily on the basis of the presence of one or more of a cluster of daytime deficits, including excessive daytime sleepiness, cardiopulmonary complications, alterations of consciousness, and intellectual deficits. Although the repetitive nocturnal respiratory disturbances associated with SAS have long been thought to be the causes of these waking deficits (Guilleminault et al., 1976), only during the last several years have systematic attempts been made to describe and quantify the nature of the relationship between apnea activity and daytime sequelae. As will be seen below, sound evidence establishing the etiologic importance of sleep-disordered breathing in the development of waking sequelae in SAS patients has begun to accrue, with the more sophisticated studies in this area implicating hypoxemia as the relevant proximal cause.

Paralleling this increase in the number of studies investigating the concomitants of apnea activity in SAS patients has been an increased interest in establishing the incidence of nocturnal respiratory disturbance in nonclinical populations. These studies have revealed the occurrence of sleep-disordered breathing in often very high proportions of segments of the general population. Aging persons in particular have been found to exhibit striking incidence rates for sleep apnea activity. Such findings raise the questions of whether the waking deficits found to be related to apneas and oxygen desaturations in SAS patients are also found in nonclinical populations exhibiting sleep-disordered breathing and to what degree. A few very recent studies have addressed these questions with respect to aging persons; however, each of these studies has focused on only one or a subset of the likely concomitants of apnea activity, and their findings are in need of both replication and extension to the full range of likely daytime sequelae of nocturnal repiratory disturbance.

The present study will examine the correlates of nocturnal respiratory disturbance in a nonclinical population expected to display a wide range of apneic events: elderly males. The relationship between respiratory indices and detailed measures of demographic, health, sleep/wake, and cognitive variables in this population will be examined. Further, a replication of previous findings indicating a high incidence of apnea activity and a high prevalence of 'clinically significant' levels of apnea activity in this population will be attempted. Finally, certain largely previously neglected methodological and measurement issues relating to the stability of measures of respiratory disturbance over time and to the relative utility of the myriad possible measures of respiratory disturbance in predicting waking deficits will be examined. A review of the information currently available on various aspects of Sleep Apnea Syndrome and the phenomemon of nocturnal respiratory disturbance in general will be presented as background for the study. The diagnosis and characteristics of SAS, the incidence of SAS and sleep apnea activity in young and old populations, and the deficits associated with SAS and sleep apnea activity will be reviewed. As will be seen, the daytime concomitants of varying levels of sleep apnea activity in healthy younger subjects are not well understood, and very little research has examined these concomitants in elderly subjects. This will be followed by an examination of current thinking concerning the specific etiology of the possible neuropsychological concomitants of sleep-disordered breathing. Finally, some methodological issues will be raised and literature pertinent to these issues will be reviewed with an eye toward identifying questions that remain as yet unanswered.

Definitions/Terminology

Sleep apneas have been defined as cessations of airflow at the mouth and nose which last for 10 seconds or longer (Guilleminault et al., 1976). Sleep hypopneas have generally been defined as reductions in airflow of 50% or more (without complete cessation) at the mouth and nose (Carskadon et al., 1980). Oxygen desaturation is a frequent but not invariant concomitant of apneas and hypopneas. When a respiratory event begins, arterial oxygen saturation usually begins to fall and may continue to fall until normal breathing resumes. Sleep Apnea Syndrome (SAS) is a clinical entity described in a recent nosology published by the Association of Sleep Disorders Centers (ASDC, 1979) as a potentially lethal condition characterized by multiple apneas, repetitive episodes of loud snoring, excessive daytime sleepiness, and possible cardiopulmonary complications, alterations of consciousness, and intellectual deficits. The episodes of apnea are thought to play a causal role in the production of the other deficits associated with SAS (Guilleminault et al., 1976); because those episodes lend themselves to objective quantification they have taken on increasing importance as diagnostic markers of the syndrome. Guilleminault et al. (1976) suggested that the occurrence of at least 30 apneic episodes during 7 hours of sleep was diagnostic of SAS, and they validated this criterion through a comparison of symptomatic (presumably snoring and excessively sleepy) and asymptomatic younger subjects. These workers later proposed the use of an Apnea Index score (AI; number of apneas divided by number of hours of sleep) in excess of 5 as a cut-off for the diagnosis of SAS (Guilleminault et al., 1978). Carskadon et al. (1980) combined apneas and hypopneas to form an apnea +

hypopnea index (AHI) and suggested that a score of 5 or greater be considered diagnostic of SAS. Subjects exhibiting lower levels of sleep-disordered breathing (that is, AI or AHI scores greater than 0 but less than 5) have been labeled as experiencing sleep apnea activity (SAA). These criteria have been widely adopted in both clinical and research settings.

Characteristics of SAS Patients

Three relatively large samples of SAS patients have been described in the literature. Guilleminault et al. (1978) found that of 50 patients diagnosed with SAS during a 6 year period, 48 were male. Thirty-nine of the 50 were referred with complaints of excessive daytime sleepiness, 7 were referred by their spouses who described loud snoring and abnormal movements during sleep, and the remainder were referred with complaints of morning nausea, morning headaches/confusion, or hypertension. Sixty percent of these patients were more than 15% overweight. Other frequently reported complaints included personality changes (broadly and anecdotally defined), impotence, and intellectual deterioration (usually attention/concentration difficulties; no formal testing was conducted). These patients ranged in age from 28 to 62. Kales et al. (1985a) reported on 50 consecutive patients (aged between 25 and 68) diagnosed with SAS at a sleep disorders center. Eighty-six percent of these patients were male, all complained of debilitating daytime sleepiness, and 86% exhibited cardiovascular abnormalities (hypertension or arrhythmias). Forty-six of the 50 patients were snorers and all but 9 were clinically obese. Other frequently reported complaints included increased body movements during sleep, profuse sweating during sleep, bedwetting, intense morning headaches, morning fatigue, impaired morning alertness, and decreased sexual desire. Weitzman et al. (1980) described a group of 10 SAS patients who were male, consistently overweight, hypertensive, excessively sleepy during the day, and between the ages of 38 and 47. From these data it would appear that the 'typical' SAS patient is an overweight middle-aged male who often suffers from deleterious health and intellectual changes.

Incidence of Sleep Apnea Activity

In studying the incidence of sleep apnea activity and the prevalence of clinically significant levels of sleep-disordered breathing in younger and older subjects, researchers have typically recruited subjects either from clinical sources (usually sleep disorder clinic patients with very prominent complaints about their sleep) or from the community. Some studies using community volunteers attempted to screen out subjects with sleep complaints, while others made no such attempt. The 13 studies which drew subjects from community sources will be discussed first.

Webb (1974) studied a sample of 20 "non-ill" males without sleep complaints, 11 of whom were between the ages of 19 and 45 and 9 of whom were aged 46 to 63. Eighty-two percent of the subjects aged 46 to 63 exhibited at least one episode of sleep apnea (range: 1-5) while none of the younger subjects experienced sleep apnea. The author concluded that the presence of apnea activity is positively related to age. Guilleminault et al. (1978) recruited a sample of 20 noncomplaining subjects between the ages of 40 and 60 and found that the males experienced an average of 7 apneas per night (range: 1-25) and that the females experienced an average of 2 apneas per night (range: 0-5). Block et al. (1979) recruited a sample of 49 subjects without sleep or breathing complaints (#males: 30; age range: 24-62; #females: 19; age range: 20-51). Forty percent of the males and 15% of the females experienced at least one episode of sleep apnea. The males with apnea exhibited a mean of 4.2 episodes while the females with apnea exhibited a mean of 3. Block et al. (1979) also reported data pertaining to the incidence of nocturnal oxygen desaturation (a frequent concomitant of sleep-disordered breathing) in these noncomplaining subjects. Fifty-seven percent of the males experienced at least one desaturation of 4% or greater; none of the females exhibited desaturation. Both age and weight:height ratio were found to be significantly positively related to number of desaturations but only weight:height ratio (and not age) was found to be significantly positively related to number of apnea episodes. Block et al. (1980) compared a group of 20 post-menopausal women (age range: 50-74) with a group of 18 pre-menopausal women (age range: 20-51). All subjects were without sleep and breathing complaints. There was no significant difference in the number of women in the two age groups exhibiting sleep apneas (although 40% of the older and only 11% of the younger subjects exhibited apneas); however, a significantly higher number of the older women exhibited desaturations ≥4% and hypopneas. The older women with apneas averaged 39 episodes per night while the younger subjects with apnea averaged 6.

Bixler et al. (1982) recruited a sample of 100 subjects who were carefully screened for the absence of sleep complaints, physical problems, and medication usage. The 41 males and 59 females were grouped into 3 age blocks: 18-29, 30-49, and 50-74. None of these non-complaining subjects achieved an AI score ≥5; however, 14.6% of the men and 10.2% of the women experienced between 3 and 29 apnea episodes per night (males with apnea averaged 10.5 episodes; females averaged 8.5 episodes). The incidence of sleep apnea activity increased across the three age groups (3.3% vs. 12.8% vs. 20%) and there was a significant positive correlation between age and presence of sleep apnea activity. The same group of researchers later reported incidence data from an expanded number of older non-complaining subjects (Bixler et al., 1985). Sixty subjects aged 50 or older (many of these were subjects studied in Bixler et al., 1982) were compared with 69 subjects between the ages of 18 and 49. Eight percent of the older males and none of the older females and younger subjects achieved an AI score ≥ 5. Thirty-two percent of the older males and 23% of the older females exhibited between 3 and 29 apnea episodes (the figures for younger males and females were 10% and 7%, respectively). A significantly higher number of older subjects (27% vs. 9%) exhibited between 3 and 29 apnea episodes per night and age was significantly positively correlated with both the presence of apnea activity and AI. Age was not significantly related to apnea activity within the exclusively older group. In both age groups there was a (non-significant) trend toward a higher AI score and incidence of apnea activity in males. These researchers also reported oxygen saturation data indicating that the minimum saturation reached during sleep did not differ between males and females and between older and younger subjects. They did not report correlations between age and desaturation data.

Reynolds et al. (1985), in a study designed to compare the incidence of sleep apnea activity in older subjects falling into one of three groups (demented, depressed, healthy control), reported that of a group of 23 non-demented, non-depressed subjects without sleep complaints between the ages of 58 and 82, 4.3% attained an AI score ≥ 5 (11% of the males and 0% of the females). The average AI score in this sample was 1.3 and the average Apnea + Hypopnea Index score was 1.8. These workers did not report data pertaining to the incidence of sub-clinical levels of apnea activity. In a study similar to Reynolds et al. (1985), Hoch et al. (1986) recruited 56 healthy subjects between the ages of 58 and 82 who reported no sleep/wake complaints and who demonstrated on psychological testing that they were non-demented and non-depressed. Of these healthy controls, 5.4% attained an AI score ≥ 5. Separate percentages for males and females were not reported. These workers also did not report incidence data for subclinical levels of apnea activity.

Carskadon and Dement (1981) recruited 18 male and 22 female elderly subjects from nonclinical sources. Subjects who "complained spontaneously" of sleep problems were excluded, but this criterion was not rigidly applied. The males ranged in age from 63 to 86 and the females ranged from 62 to 85 years of age. Eighty-eight percent of the males and 72% of the females experienced at least one episode of apnea or hypopnea; 39% of the males and 18% of the females achieved AI scores ≥ 5 (44% and 32% achieved Apnea + Hypopnea Index scores ≥ 5). Males experiencing apnea exhibited a mean of 51 episodes and females with apnea averaged 34 episodes. A trend toward an increase with age (within this elderly group) in number of sleep apnea events was apparent for the females only. Lavie (1983) studied 78 male industrial workers (age range is not reported, but it may be assumed from their active employment status that most subjects were middle-aged or younger). Findings indicated that 20.5% of these subjects achieved an AI score ≥5 and 14% achieved an AI score ≥10. The average age of the workers with AI scores ≥10 was significantly higher than the average age of the workers without apnea. Ancoli-Israel et al. (1986) report apnea incidence data derived from 425 randomly selected subjects aged 65 to 101. The at-home recording device used in this study provided only very rough measures of respiratory activity and sleep. Of the 195 males (mean age: 73.5) and 230 females (mean age: 72.8), 24% achieved AI scores ≥5. The mean Apnea Index for the entire sample was 3.97 and for those with AI scores ≥5 the mean was 13.2. The males demonstrated a significantly higher prevalence of AI ≥5 (28% vs. 19.5%) and a significantly higher mean AI (7.5 vs. 3.4); there was no significant difference in the mean age of those above and below AI=5 within this exclusively older sample.

McGinty et al. (1982) studied 26 males between the ages of 55 and 75, selected without reference to sleep or respiratory complaints. These researchers concentrated exclusively on oxygen desaturation data; thus, they do not report on the incidence of sleep apnea activity or on the prevalence of clinically significant levels of apnea activity. Sixty-two percent of these elderly males experienced more than 8 episodes of desaturation ≥4% per hour and 46% experienced more than 20 such episodes per hour. Those subjects exhibiting more than 8 desaturations per hour experienced an average of 28 such episodes per hour; the remaining subjects exhibited an average of 4 desaturations per hour. These two groups of older males did not differ significantly in age. Finally, Smallwood et al. (1983), in a study designed to compare the prevalence of a clinically significant level of apnea + hypopnea activity in elderly controls (age range: 50-80) and elderly Alzheimer's patients, found that of 24 male and 10 female controls, 46% and 0%, respectively, attained A+H Index scores greater than or equal to 5. Apnea + Hypopnea Index was significantly greater in the elderly male controls than in a group of young male controls. The elderly males exhibited a mean A+H Index score of 7.2; the elderly females averaged 0.71.

The above studies report widely divergent incidence rates for sleep apnea activity and prevalence rates for clinically significant levels of apnea activity. For example, within samples of elderly males, separate studies reported that 32%, 82%, and 88% of the subjects experienced at least one episode of apnea. Similarly, studies reported that 8%, 11%, 39%, and 28% of elderly males attained Apnea Index scores ≥ 5. These discrepancies seem attributable to the differing subject selection strategies used by these studies. In the case of both sets of percentages the two latter (higher) figures were derived from samples not screened for sleep complaints. The other (much lower) figures were derived from samples composed of subjects who, after careful screening, were found to have no complaints about their sleep. It seems apparent that excluding subjects who are dissatisfied with their sleep greatly reduces the observed incidence of sleep apnea activity. Each study which included both male and female older subjects found the males to exhibit higher incidence rates for apnea activity (32% vs. 23%; 88% vs. 72%) and a higher prevalence of AI≥5 (8% vs. 0%; 11% vs. 0%; 39% vs 18%; 28% vs. 19.5%). Two studies reporting on the prevalence of Apnea + Hypopnea Index scores ≥5 in older samples found similar sex differences (46% vs. 0%; 44% vs. 32%). Those studies reporting incidence rates (ranging between 0% and 11%) and prevalence rates (0%) in younger subjects suggest that amount of apnea activity is strongly positively related to age. This conclusion is supported by the findings of the three studies (Webb, 1974, Bixler et al., 1982, and Bixler et al., 1985) which found a substantial positive relationship between age and amount of apnea activity and the two studies (Block et al., 1979 and Block et al., 1980) which found a significant relationship between age and both incidence and amount of nocturnal oxygen desaturation. These latter studies failed to demonstrate a significant relationship between age and apnea activity, although age-related trends were apparent. The findings of McGinty et al. (1982) indicate that the very high numbers of respiratory events observed in older males are accompanied by equally high numbers of desaturations ≥4%.

The second sampling strategy (i.e., the recruitment of subjects with prominent sleep complaints) has been utilized by four studies reporting apnea incidence data. Kales et al. (1982) wished to examine the possible role of sleep apnea in the etiology of insomnia. They studied 200 consecutive sleep disorders clinic patients with a primary complaint of chronic difficulties initiating or maintaining sleep. These 82 males and 118 females ranged in age from 18 to 78 with a mean age of 42.3. None of these insomniac subjects exhibited what the authors considered to be a clinically significant number of apneas per night ($\geq$30), but 10.5% experienced between 3 and 29 episodes (males: 13.4%; females: 8.5%). Subjects with sleep apnea activity averaged 9.1 episodes and were significantly older than those without. Ancoli-Israel et al. (1981) recruited 24 elderly subjects whose answers to a questionnaire raised suspicion of the presence of sleep apnea or nocturnal myoclonus. The 11 males and 13 females ranged in age from 58 to 79. Fifty-four percent of the males and 23% of the females achieved AI scores greater than 5. Twenty-two of the 24 subjects (91%) exhibited at least one episode of sleep apnea; within this subsample, the males averaged 53 apneas and the females averaged 32. Reynolds et al. (1980) studied a group of 27 patients aged 55 or older (18 males, 9 females) referred to a sleep disorders clinic with complaints of either excessive daytime sleepiness or chronic insomnia (most presented with the latter complaint).

Although no mention is made of the exact criterion applied, the authors report that 18.5% of these older subjects exhibited a level of apnea activity consistent with a diagnosis of SAS. All of the patients diagnosable with SAS were male. Coleman et al. (1981) report apnea incidence data derived from 83 elderly consecutive referrals to a sleep disorders clinic. These subjects, aged 60 to 85, manifested a wide range of sleep/wake complaints. Seventy-two percent of these complaining elderly patients experienced at least 30 apnea episodes per night and the average number of events for all subjects was 150.

In summary, two studies concentrating specifically on elderly subjects with sleep complaints found a remarkably high incidence and level of sleep apnea activity, while two others found lower rates. These latter studies (Kales et al., 1982 and Reynolds et al., 1980) found that only 0% and 18.5% of older males exhibited very high numbers of apneas. In contrast, Ancoli-Israel et al. (1981) and Coleman et al. (1981) found 55% and 72% of their older males to exhibit high numbers of events. Because the measurement and scoring methodologies used by these 4 studies were essentially identical, the wide discrepancy must be attributed to systematic differences in the samples studied. The most obvious difference in sample composition lies in the types of sleep complaints for which patients were referred to the various sleep disorder clinics. The Kales et al. and Reynolds et al. samples were made up almost exclusively of patients with complaints of insomnia; the Ancoli-Israel et al. and Coleman et al. samples presented with a more heterogeneous set of complaints (and in particular included substantial proportions of subjects with complaints suggestive of sleep apnea). It may be concluded from these studies that 1) a complaint of insomnia is not predictive of an increased level of sleep apnea, and 2) heterogeneous samples of older sleep disorders clinic patients display a remarkably high prevalence rate for clinically significant levels of sleep apnea activity. The Kales et al. (1982) findings, derived from insomniacs of all ages and indicating a significantly increased incidence of apnea activity in older patients, suggests (in the absence of direct young vs. old comparisons in the other three studies) that age is importantly and positively related to the incidence of sleep apnea activity in complaining individuals.

The following broad conclusions may be drawn from the 17 above-reviewed studies: 1) sizable proportions of elderly subjects without prominent sleep or respiratory complaints experience at least some sleep apnea each night; 2) amount of apnea activity is age-related regardless of subject selection strategy; 3) perhaps as many as 39% of healthy elderly males selected without regard to sleep or respiratory complaints experience what has come to be regarded as a clinically significant amount of sleep apnea activity; and 4) the high numbers of respiratory events experienced by elderly males are accompanied by high numbers of oxygen desaturations. These findings are compelling, given the widespread belief that the waking deficits of SAS patients are directly attributable to the high numbers of nocturnal respiratory events they experience, and they suggest these questions: What, if any, are the ramifications of the near-ubiquity of sleep apnea and desaturation activity in elderly subjects, and do nonclinical elderly subjects with high numbers of desaturations suffer from SAS-like daytime deficits? The present study attempted to answer these questions in two ways. First, by examining correlations between indices of sleep-disordered breathing and measures of the deficits commonly seen in SAS patients. Second, by identifying nonclinical elderly subjects with high numbers of desaturations and comparing their health, sleep/wake, and cognitive status to that of subjects exhibiting a lower level of desaturation activity. The resulting patterns of between-group differences allowed for judgments to be made concerning the effects of relatively high numbers of desaturations.

The cardiopulmonary complications, hypersomnolence, and assorted other negative clinical features (e.g., intellectual deterioration and disrupted nocturnal sleep) commonly reported in patients diagnosed with Sleep Apnea Syndrome are thought to be related to the repetitive sleep apneas, hypopneas, and desaturations those patients experience. It would seem important to examine the research findings on which that conclusion is based and to examine research findings with some bearing on the question of whether high levels of apnea in nonclinical samples are also associated with daytime sequelae. If, as the above-reviewed studies indicate, aging is associated with an increase in apnea activity, and if higher levels of apnea are associated with waking sequelae in nonclinical samples (as suggested by, among others, Ancoli-Israel et al., 1981, and Carskadon and Dement, 1981), then many elderly individuals would appear to be at particularly high risk for those deficits. As will be seen, there is much evidence that strongly suggests a connection between sleep-disordered breathing and various deficits in SAS patients; however, there is a striking paucity of research examining the possibility of a relationship between apnea and waking deficits in nonclinical subjects, and almost no research that has looked specifically at nonclinical older subjects.

Deficits Associated with Sleep Apnea Syndrome and Sleep Apnea Activity

Cardiological Deficits

Many studies have investigated the relationship between sleep-disordered breathing and cardiological functioning. The great majority of these studies have looked only at the cardiac functioning of subjects with very high levels of apnea activity (usually sleep disorder clinic patients diagnosed with SAS). The three studies reviewed at the end of this section (Berry et al., 1986b; Ancoli-Israel et al., 1981; Lavie, 1983) compared the incidence of hypertension in nonclinical groups stratified by level of apnea activity and are especially pertinent to the justification for, and the findings of, the present study. The following studies report two kinds of data pertaining to cardiac functioning: 1) data concerning the possible long-term effects of sleep-disordered breathing (waking systemic hypertension and various other waking abnormalities such as arrhythmias, ventricular and anterior hypertrophy, cardiomegaly, etc.) and 2) data concerning the possible acute effects of apnea on cardiac functioning during sleep (bradycardia, tachycardia, rises in systemic and pulmonary arterial pressure, PVC, etc.).

Schroeder et al. (1978) studied 22 male SAS patients aged between 30 and 63 (mean: 47). Six (27%) of these subjects had waking systemic hypertension and several others exhibited waking cardiac abnormalities (left ventricular hypertrophy, left anterior hemiblock, ST-T wave abnormalities, borderline cardiomegaly). While asleep, twenty of the 22 patients manifested significant rises in systemic arterial pressure, and 21 manifested moderate rises in pulmonary arterial pressure. These rises coincided with episodes of sleep apnea. Treatments aimed at either mitigating the effects or eliminating the occurrence of apneas (tracheostomy or oxygen administered during sleep) virtually eliminated the transient abnormalities, thus strongly implicating the apneas in their etiology. Tilkian et al. (1978) studied 25 male SAS patients aged between 30 and 63 (mean: 44). Forty-eight percent of these patients exhibited waking systemic hypertension, while 24 of the 25 demonstrated marked sinus arrhythmias, typically bradycardia, during apneas. Other apnea-contingent abnormalities included prolonged sinus pauses, ventricular tachycardia, and atrial tachycardia. Tracheostomy completely abolished marked sinus arrhythmias and most of the other transient abnormalities in the 17 patients who received this treatment, again strongly implicating the apneas in their etiology. Zwillich et al. (1982) report cardiopulmonary data derived from 6 male SAS patients aged 23 to 68 (mean: 41.8). None of these subjects reported a history of systemic hypertension (surprisingly, these workers failed to measure waking blood pressure); normal waking sinus rhythm was present in all subjects, but bradycardia was observed during 95% of all apneas and became more marked as apnea length increased and arterial oxygen saturation decreased. Bradycardia was eliminated in all 4 of the patients administered oxygen-enriched air while asleep. The authors concluded that bradycardia occurs during almost all apneas and that the degree of bradycardia depends upon the degree of desaturation resulting from those apneas.

Guilleminault et al. (1978) reported that of a group of 48 male and 2 female SAS patients (mean age: 45; range 28-62), 52% were hypertensive. Kales et al. (1985a) found that 72% of a sample of 50 SAS patients (43 males, 7 females; mean age: 46) were hypertensive. Coverdale et al. (1980) report that of a sample of 8 SAS patients (7 males, 1 female; ages not reported), 50% had waking systemic hypertension. None of these patients demonstrated severe bradycardia or tachycardia during apneas. Orr et al. (1979) studied two small groups of SAS patients, one consisting of 4 men with complaints of excessive daytime sleepiness, and the other consisting of 4 men with equally high numbers of apnea events but without complaints of sleepiness. All of the somnolent patients were found to suffer from waking right-sided heart failure as well as frequent arrhythmias during apneas; none of the nonsomnolent patients demonstrated these deficits. These two groups differed on one important dimension: the somnolent patients experienced substantially greater oxygen desaturations during apneas than the nonsomnolent patients. In a study designed to directly investigate the relationship between apnea-contingent oxygen desaturation and transient apnea-contingent arrhythmias, Shepard et al. (1985) studied 31 male SAS patients with an average age of 55 (range 30-76). Forty-eight percent of these subjects were found to be hypertensive. Apnea-related premature ventricular complexes (PVC) were observed during the sleep of 74% of these subjects. A significant correlation between PVC frequency and oxygen desaturation was found only for those subjects who displayed desaturations to 60% or lower. The authors concluded: "Patients with obstructive sleep apnea are at relatively low risk of developing ventricular arrhythmias provided oxygen saturation remains greater than 60%, while those with saturation below 60% are at increased risk and should be managed accordingly" (p.335). Fujita et al. (1981) reported that of a sample of 12 male SAS patients (ages not reported), all suffered cardiac arrhythmias while asleep.

Berry et al. (1986b) compared three groups of middle-aged male subjects (all were nonclinical volunteers; sample mean age: 50; range: 30-75) formed on the basis of Apnea + Hypopnea Index scores. The groups did not differ significantly in either age or weight. The group with AHI scores ≥5 did not differ significantly on diastolic or systolic blood pressure readings or on reports of a history of systemic hypertension from a group of subjects with AHI scores between 0 and 5 and a group with AHI=0. For the sample as a whole, a significant positive correlation was found between systolic blood pressure and number of desaturations ≥4%. Ancoli-Israel et al. (1981) compared 9 elderly subjects who attained AI scores ≥5 with 15 elderly subjects with AI scores less than 5. These groups did not differ significantly in age. All subjects were recruited from nonclinical sources. The high sleep apnea group did not report significantly greater frequencies of hypertension or heart failure than the low sleep apnea group. It should be noted that these workers did not directly measure their subjects' blood pressure. Lavie (1983) compared 11 middle-aged males with AI scores $\geq$10 with 67 middle-aged males who attained AI scores less than 10. The high AI group was found to be significantly older than the low AI group; the groups did not differ in weight. All subjects were recruited from nonclinical sources. A significantly higher proportion of the subjects in the high AI group were found to have hypertension (36% vs. 7%).

The above studies indicate that SAS patients very frequently suffer from both long term waking and short term sleeping cardiac abnormalities. Incidence rates for diagnosable hypertension ranged from 27% to 72%, with the majority of studies indicating that roughly 1/2 of all SAS patients are hypertensive. It is quite difficult, however, to interpret these findings because none of the studies looking specifically at SAS patients recruited age- and weight-matched non-SAS patient control groups. Both age (see previous section of this chapter) and weight (Bixler et al., 1982; Kales et al., 1982; Block et al., 1980; Block et al., 1979) have been found to be positively related to amount of apnea activity, and both of these variables are known to predict hypertension. Those studies which simply report hypertension rates in SAS patients cannot determine the contribution of sleep-disordered breathing to the development of hypertension in isolation from other known causal factors. It seems very likely that the increased incidence of hypertension in SAS patients is at least partly attributable to their tendency to be older and heavier than the general population, and it is possible that age and weight account completely for the high incidence of hypertension in SAS patients. Clearly, any comparison of blood pressure measures in groups differing on amount of apnea or desaturation activity must control for the effects of age and weight.

Every study (with the exception of one) reporting data pertaining to acute apnea-contingent cardiac complications found very high frequencies of arrhythmias, acute rises in blood pressure, and PVC. Treatments that abolished apneas also abolished these acute complications, strongly implicating the apneas as causal factors. Evidence indicating that the oxygen desaturation engendered by sleep-disordered breathing is the key etiologic factor in the manifestation of sleeping arrhythmia has begun to accrue. Orr (1986) reviewed these oxygen desaturation findings and concluded that although hypoxemia is not the sole predictor of ventricular dysfunction, strong enough evidence of an important relationship now exists, and individuals with oxygen saturation levels in the range of 60% or below "... should be singled out for immediate aggressive treatment intervention" (p.2).

Only three studies have compared incidence rates for hypertension from nonclinical subjects stratified by level of apnea activity. One study (Ancoli-Israel, 1981) found no significant increase in hypertension in high AI elderly subjects but this is a relatively uninformative finding as they relied solely on patient reports of a history of hypertension and did not directly measure blood pressure. They thus could not conduct correlational analyses relating amount of apnea or desaturation to waking blood pressure. Lavie (1983) did find an increased incidence of hypertension in nonclinical middle-aged subjects with substantial amounts of apnea compared to subjects with varying lesser degrees of apnea activity, but this study failed to control for the significantly higher age of the high apnea group (the groups did not differ in weight). Finally, Berry et al. (1986b) found no increased incidence of hypertension in middle-aged males displaying high levels of apnea compared to age- and weight-matched subjects with lesser amounts of apnea, but they did find a significant positive correlation between number of desaturations and waking systolic pressure --suggesting that desaturations take a toll on waking cardiac functioning even in subjects who do not meet 'clinical' criteria for the diagnosis of SAS. This finding is limited, however, by the fact that no effort was made to partial out from this correlation the reported significant positive relationships between both age and weight and measures of desaturation. The independent contribution of desaturation to higher blood pressure thus remains unknown from their data. In general, then, it is simply not clear from the available evidence whether a high level of sleep-disordered breathing is predictive of an increased incidence of hypertension in nonclinical subjects. The present study attempted to investigate the relationship between nocturnal respiratory activity and blood pressure while controlling, where appropriate, for other variables known to predict blood pressure by recruiting elderly males with varying levels of desaturation activity and then determining both the incidence of hypertension in age-matched groups stratified by level of desaturation and the partial correlation between various measures of sleep-disordered breathing and waking blood pressure, controlling for age and weight.

Hypersomnolence

A complaint of excessive daytime sleepiness (EDS) is one of the formal requirements for a diagnosis of Sleep Apnea Syndrome (ASDC, 1979) and from this one might assume that such complaints are invariably present in patients labeled 'SAS'. In fact, EDS is described by every SAS patient studied in reports by Tilkian et al. (1978), Schroeder et al. (1978), Weitzman et al. (1980), Sullivan and Issa (1980), Coverdale et al. (1980), Garay et al. (1981), Fujita et al. (1981), Zwillich et al. (1982), Kales et al. (1985a), and Guilleminault et al. (1986). However, a focus on a high level of apnea activity (usually an AI score ≥ 5) as diagnostic of SAS has led various investigators to apply the label 'asymptomatic SAS' to those subjects with AI scores ≥ 5 who do not complain of EDS. Orr et al. (1979), Lavie (1983), Smirne et al. (1980), Guilleminault et al.

(1978), and Sink et al. (1986) have identified and described such 'asymptomatic' subjects. Dement et al. (1978) describe the justification typically offered for this labeling practice:

> It is not uncommon . . . to see a patient fall asleep literally seconds after he has stoutly maintained that he is 'wide awake'. It is absolutely clear that some patients deny the existence of severe sleepiness either because it is psychologically repugnant or because they have lost their frame of reference for true alertness. Some patients are simply and honestly unaware of their countless microsleeps and lapses of attention (p.26).

This justification confounds two issues, one methodological and the other theoretical. It is at least implied in the above statement that if a perfect measure of sleepiness existed (that is, one not susceptible to distortion by the subject) all persons with high levels of apnea activity would be shown to be "symptomatic." Although it is helpful and useful that Dement et al. call attention to the need for a refinement of measures of sleepiness, in doing so they regard as settled a question that is in fact far from settled and which cannot be decided on the basis of belief but rather on the basis of experimental inquiry. That question concerns whether it is possible to experience consistently high numbers of apneas without experiencing excessive daytime sleepiness. In addition to leading to the premature closure of an important issue, the use of the term 'asymptomatic' promotes the illogical concept of a "disease" without symptoms. The promotion of such a concept would seem to be of benefit only to sleep disorder clinics seeking to attract patients.

The unreliabilty of global self-reports of non-EDS can be circumvented through a more objective quantification of sleepiness, and several studies have in fact attempted to go beyond a reliance on patient self reports to directly measure daytime sleepiness. Dement et al. (1978) used the Multiple Sleep Latency Test (MSLT) to compare the daytime sleepiness of 16 SAS patients and 6 matched controls without sleep apnea. The MSLT is a procedure in which subjects are placed in a quiet, darkened room during the day and instructed to attempt to fall asleep. Their ability to do so is measured through continuous monitoring of EEG. Thus, a patient with EDS will presumably show a very short latency to sleep in comparison to normals. The MSLT, to be valid, should be administered repeatedly at regular intervals throughout the day. Dement et al. found that their SAS patients fell asleep consistently and significantly more quickly than the matched controls. The average sleep latency of the SAS patients was well within the range of 'pathological' sleepiness (less than 5 minutes). Roth et al. (1980), Hartse et al. (1980), Zorick et al. (1982), and Knight et al. (1987) have performed replications of the Dement et al. study; all found significantly greater sleepiness in SAS patients compared to non-SAS subjects and very high proportions of SAS subjects meeting the criterion for pathological sleepiness. Berry et al. (1986b) also attempted to replicate these findings, using nonclinical middle-aged male subjects stratified by level of apnea activity, but found no difference in MSLT results when subjects with AHI scores ≥5 were compared with subjects without apnea activity. This is a somewhat flawed finding, however, as the MSLT procedure was performed only twice for each subject (in the late afternoon and then early evening). Importantly though, Berry et al. did find evidence of a relationship between apnea activity, in the sample as a whole, and daytime sleepiness, in the form of significant positive correlations between both Apnea + Hypopnea Index score and Number of Desaturations ≥4% and questionnaire findings concerning number of daytime naps typically taken. Similarly, Timms et al. (1985) correlated various measures of nocturnal oxygen desaturation with MSLT results derived from 42 SAS patients. They found several significant correlations indicating that degree of desaturation is predictive of daytime sleepiness. Roth et al. (1980) performed the same analyses with a much smaller sample of SAS patients (n=10) and found no significant relationship between desaturation indices and MSLT results; they did, however, find that a higher Apnea Index predicted greater daytime sleepiness. Two other studies provide information relevant to the question of whether apnea activity and/or oxygen desaturation is related to daytime sleepiness. Orr et al. (1979) compared 4 SAS patients with complaints of EDS and 4 SAS patients without EDS and found that the two groups differed, on average, in the degree of desaturation they experienced during apneas: the EDS group exhibited much more severe desaturations. This finding supports the idea that apnea-contingent hypoxemia is an important cause of daytime sleepiness. Sink et al. (1986) replicated this study with much larger groups of subjects with and without complaints of daytime sleepiness (matched for a high level of apnea) and found essentially the same group differences in degree of apnea-contingent desaturation.

The above studies indicate rather clearly that 1) SAS patients exhibit a very high incidence of excessive daytime sleepiness, and 2) this sleepiness seems to be related to the multiple apnea-contingent oxygen desaturations those patients experience. These studies do not, however, speak to the nature of the causal relationship between sleep-disordered breathing and daytime sleepiness. One hypothesis concerning this causal connection asserts that it is the high degree of sleep disruption experienced by SAS patients which leads to their daytime sleepiness. This hypothesis is derived from research indicating that periodically disturbed sleep is less restorative than nondisturbed sleep, even when total sleep time is relatively unaffected (Bonnet, 1985; Bonnet, 1986). As will be seen in the next section, research indicates that episodes of apnea and hypopnea are almost invariably followed by a brief arousal (usually less than 30 seconds in duration) during the resumption of breathing. It has been suggested that these arousals which disrupt the continuity of sleep predict daytime sleepiness in SAS patients. Three studies have tested this hypothesis. Roth et al. (1980) found that the variable "arousals subsequent to respiration" was the single best predictor (r= -.52) of daytime sleepiness (as measured by the Multiple Sleep Latency Test) in a group of 10 SAS patients, and Stepanski et al. (1984) found a significant correlation (r= -.33) between number of brief arousals and MSLT results in 15 SAS patients. Bonnet et al. (1986) divided a group of 12 SAS patients into 3 subgroups on the basis of AI scores (AI between 5 and 20, AI between 20 and 45, and AI greater than 45) and then compared these groups on daytime sleepiness, EEG sleep variables, and 3 measures of 'sleep continuity'. The sleep continuity variables consisted of the median length of time between each apnea event and the median of the longest period and of the 5 longest periods of undisturbed sleep within every 100 apnea events. These variables thus reflected the extent to which each patient obtained uninterrupted sleep. Results indicated that for all of the patients apneas tended to occur in clusters at the rate of 1 per minute, but that those patients with lesser amounts of apnea accrued a median of 80 and 24 minutes of undisturbed sleep between clusters; the patients with severe apnea accrued a median of only 9 minutes of undisturbed sleep between clusters. These differences between the groups were significant. It is interesting to note that while the groups also differed in sleepiness, none of the EEG sleep variables (Time in Bed, Sleep Latency, Sleep Efficiency, stage percentages) differed significantly between groups, suggesting that discontinuity of sleep and not sleep structure predicts increased daytime sleepiness. This suggestion was confirmed by the finding that the median of the longest periods between apnea events correlated significantly (r= -.68) with daytime sleepiness; Apnea Index and EEG variables did not correlate significantly with sleepiness. The authors concluded "... it may be more important to track periods of consolidated sleep rather than simply numbers of apneic events in predicting the extent of daytime sleepiness" (p.105). These findings support the notion that it is the disruption of sleep attendant upon periodic oxygen insufficiency which determines the level of daytime sleepiness in SAS patients.

In summary, although a high proportion of SAS patients complain of excessive daytime sleepiness, some do not. Dement et al. (1978) suggest that SAS patients who do not report EDS cannot be relied upon for valid self-report because their internal norms for sleepiness have been distorted during years of almost constant daytime drowsiness. This (in part) is a measurement issue which can be addressed through the use of multiple strategies for measuring daytime sleepiness, and the present study utilized several approaches to the measurement of this variable. There is some evidence indicating that the key etiologic factor in the development of apnea-related EDS is the degree of sleep disruption caused by the arousals which follow oxygen desaturation. The present study attempted to replicate these findings (but in an only indirect fashion as no independent measure of arousal was obtained) through the computation of correlations between various measures of nocturnal respiratory disturbance and various measures of daytime sleep tendency, and through the comparison of groups differing in amount of nocturnal desaturation on measures of sleepiness. Finally, and most importantly, there is a striking paucity of findings relevant to the question of whether high levels of apnea activity are predictive of daytime sleepiness in nonclinical subjects. Only one study (Knight et al., 1987) has recruited non-clinic elderly subjects (who are at very high risk for multiple apneas) with a wide range of apnea and desaturation activity for the purpose of examining correlations between nocturnal respiratory indices and measures of daytime sleepiness. This study found a significant group difference in daytime sleepiness between subjects falling above and below AI=5. However, no significant correlations between their limited measures of oxygen desaturation and MSLT results were found. Berry et al. (1986b) attempted to investigate this question (using middle-aged males); they found no relationship between nocturnal respiratory indices and MSLT results, but did find that at-home napping tendency is significantly related to increasing oxygen desaturation.

The somewhat contradictory findings of these two studies are in need of further investigation. Through the recruitment of nonclinical elderly males, the present study represents an attempt to clarify these findings and to test the Block et al. (1979) conjecture that older subjects may show a more reliable relationship between level of apnea activity and daytime sleepiness than do younger subjects.

Disruption of Nocturnal Sleep

Although the disruption of nocturnal sleep is not a formally recognized 'symptom' of Sleep Apnea Syndrome, many authors have drawn attention to the short-term arousals caused by apneas and hypopneas and to the apparent distortion of sleep stage distribution attendant upon multiple respiratory events. Further, several authors have suggested that the excessive daytime sleepiness and commonly noted intellectual changes reported by SAS patients are at least partly attributable to the fragmented sleep those patients experience (Guilleminault et al., 1976; Carskadon et al., 1980; Bonnet, 1985). Their thinking on this matter of etiology, as well as the thinking of authors who emphasize hypoxemia as an etiological factor, will be discussed in a later section. To inform that discussion, studies reporting data concerning the stages in which respiratory events tend to cluster, the differences between the sleep of SAS patients and non-SAS patients, and the effects on sleep of treatments which substantially reduce apnea activity in SAS patients, will be reviewed in this section.

Block et al. (1979) studied the sleep of 49 non-SAS subjects without sleep and breathing complaints and found that apnea events and desaturations occurred more frequently in Stages 1 and REM and less frequently in slow wave sleep than would be expected from the amount of time their subjects spent in those stages. Block et al. (1980) found that in a sample of 38 women aged 20-74 without sleep and breathing complaints, apneas and desaturations occurred disproportionately more frequently in Stages 2 and REM. Bixler et al. (1982) studied the sleep of 100 non-SAS patients aged 18-74 and found apnea events to cluster disproportionately in Stages 1 and REM and to occur less frequently than would be expected in slow wave sleep. The same group of researchers (Bixler et al., 1985) reported data from an expanded number of subjects and found similar results. Krieger et al. (1983) report data derived from 40 non-SAS patients aged 20-76 and, as did the above studies, found apneas to cluster disproportionately in Stages 1, 2, and REM.

Guilleminault et al. (1976) were one of the first sets of workers to draw attention to the fragmented sleep of SAS patients. They studied the sleep of 50 SAS patients aged 22 to 70 and found that most episodes of apnea were associated with brief (usually less than 1 minute in duration) arousals. These arousals were noted through the appearance of EEG alpha waves and an increase in chin muscle tonus upon the resumption of breathing at the end of a respiratory event. They reported that their SAS subjects experienced significantly reduced amounts of slow wave sleep (Stages 3 and 4) and significantly increased amounts of Stage 2 sleep, in comparison to age norms. Roth et al. (1980) compared the sleep of 10 SAS patients and 10 age-matched controls and found that the SAS patients experienced significantly less REM sleep and significantly more Stage 1 sleep. Further, the SAS patients manifested more shifts between sleep stages and a shorter latency to sleep upon retiring. These workers found short-term arousals to almost invariably accompany the resumption of breathing after an episode of apnea. Similarly, McGinty et al. (1982) found short term arousals to be invariably associated with episodes of apnea and hypopnea in healthy elderly males. Hesla et al. (1985) compared the sleep of 146 SAS patients and 20 controls of similar mean age and found the SAS patients to have significantly reduced slow wave and REM sleep percentages. These workers also found that an increasing Apnea + Hypopnea Index score significantly predicted less time spent in REM and slow wave sleep, more shifts between stages, and more time spent awake. Bixler et al. (1985) compared the sleep of subjects with and without sleep apnea activity and found no differences in amounts of wakefulness or Stage 1 sleep (they did not, however, perform comparisons for amounts of other sleep stages). Krieger et al. (1983), in a study of the sleep of 40 non-SAS patients of all ages, found number of apneas to be significantly positively correlated with number of shifts between sleep stages. Finally, Berry et al. (1986b) compared the sleep of nonclinical subjects stratified by level of apnea activity and found no significant differences in sleep stage amounts. Further, they found no significant correlations between indices of nocturnal respiratory disturbance and sleep stage variables. Berry et al. (and most of the other studies mentioned above) did not measure short arousals; it therefore remains unknown from their data whether high numbers of respiratory events in nonclinical subjects are predictive of high numbers of post-event arousals. However, the findings of Guilleminault et al. (1976) and Roth et al. (1980), derived from SAS patients, and the findings of McGinty et al. (1982), derived from healthy elderly males, suggest that arousals are an almost invariant result of apneas and hypopneas.

With regard to the effects on sleep of treatments aimed at reducing apnea activity in SAS patients, Weitzman et al. (1980) found that in 10 patients whose sleep was recorded before and after receiving tracheostomy, the amount of time spent in slow wave sleep was significantly increased and Stage 1 percent, number of awakenings, and number of shifts between stages was significantly decreased. In a similar study, Roth et al. (1980) found number of stage shifts and percentage of time spent in Stage 1 to be decreased after tracheostomy. Holzer et al. (1985) treated 5 SAS patients with continuous positive airway pressure (CPAP) and found slow wave and REM sleep to be significantly increased and Stage 1 sleep to be significantly decreased after treatment. Issa and Sullivan (1986) also used CPAP to treat 12 SAS patients and found similar significant increases in slow wave and REM sleep and significant decreases in Stage 1 and 2 sleep after treatment. They found CPAP to have no effect on wakefulness.

In summary, there is a striking consensus across studies concerning the temporal placement of apneas within sleep: apneas tend to cluster in light sleep (Stages 1 and 2) and in REM sleep, and they tend not to occur during slow wave sleep. From the sparse information available concerning the differences in the sleep of SAS and non-SAS subjects, it may be tentatively concluded that SAS patients experience significantly reduced amounts of either REM or slow wave sleep and correspondingly increased amounts of light sleep (Berry et al., 1986b found no such differences in a nonclinical sample). Because no differences in amount of wakefulness have been found, it appears that the effect of multiple apneas is simply a redistribution of sleep stage percentages: away from REM or slow wave sleep and toward light sleep. This redistribution is reflected in an increased number of shifts between sleep stages. Multiple, but very brief arousals (so brief that they are not traditionally scorable as 'wakefulness') almost invariably result from multiple apneas. Significantly reducing the number of nocturnal respiratory events through treatment leads directly to an increase in time spent in REM and slow wave sleep and to decreases in both time spent in light sleep and number of shifts between stages. These findings argue strongly for the view that sleep-disordered breathing causes the above-outlined distortions of nocturnal sleep. The possible relevance of these distortions and the brief arousals which appear to cause them as etiologic factors in the development of the intellectual deficits of SAS patients will be discussed shortly; it should suffice at this point to note that very little experimental work has directly tested the relationship between the disrupted sleep associated with sleep apnea activity and cognitive deficits; the present study attempted to do so.

Cognitive Deficits

Until very recently, evidence for the assertion that SAS patients suffer from intellectual deficits was exclusively anecdotal in nature (cf., Guilleminault, et al. 1976). In 1985, studies attempting to test this assertion began to appear, as did studies concerned with the possibility that sleep apnea activity is predictive of cognitive functioning in nonclinical subjects. The findings of the 8 currently-available studies providing information relevant to these two issues will be reviewed in this section.

Kales et al. (1985b) administered the WAIS-R, Wechsler Memory Scale (WMS), and Bender Test of Visual-Motor Integration to 50 SAS patients (mean age: 46; range 25-68).

No control group of non-SAS patients was used. They found that 1) 39% of these patients were impaired on the WAIS-R (defined as PIQ at least 15 points lower than VIQ); 2) 50% fell in the impaired range on the WMS (defined as a Memory Quotient less than 86); and 3) 24% showed moderate to severe impairment on the Bender (defined as a Z score below 72). These workers reported no correlations relating measures of nocturnal respiratory disturbance to cognitive functioning. Findley et al. (1986) recruited 26 SAS patients with a mean age of 52. They split their subjects into 2 age- and education-matched groups: those whose median oxygen saturation at night was below 90% were labeled Hypoxemics, and those whose median saturation was greater than 90% were labeled Non-hypoxemics. They then compared these two groups on 8 tests of neuropsychological functioning (including a short form of the WAIS-R, Trail-making part B, a measure of vigilance/eye-hand coordination, a test of rapid, complex problem-solving, and tests of immediate and delayed memory for verbal and non-verbal information). The hypoxemic group performed significantly more poorly on 4 of the 8 tests, displaying deficits in immediate and delayed verbal memory, attention/concentration (Trails B), and vigilance/eye-hand coordination. Also found was a significant negative correlation between median sleeping oxygen saturation and a rating of overall cognitive impairment made by a neuropsychologist blind to the group membership of the subjects. The correlation between this rating and number of desaturations $\geq$4% was not significant. These correlations did not control for age and education. Surprisingly, no correlations between individual test scores and measures of desaturation were computed. Norman et al. (1986) recruited 33 male SAS patients aged 19-68 and administered a 'battery of neuropsychological tests designed to assess attention, memory, the ability to shift cognitive sets, and visual-motor tracking skills' (the names of these tests are not listed). They correlated scores on these tests with Apnea + Hypopnea Index scores and mean oxygen saturation and found AHI to significantly predict poorer verbal memory and a poorer ability to shift cognitive set; they also found lower mean oxygen saturation to predict poorer visual-motor tracking skills. No effort was made in this study to partial out the effect of age and education on cognitive functioning.

In an attempt to investigate the contribution of excessive daytime sleepiness to the intellectual deficits of SAS patients, Greenberg et al. (1987) studied 14 SAS patients, 10 sleep-disordered patients without sleep apnea activity but matched with the SAS patients on level of daytime sleepiness (these were patients diagnosed with narcolepsy or nocturnal myoclonus), and 14 controls without sleep apnea or excessive daytime sleepiness. All groups were age- and education-matched and all subjects were aged less than 50. An important flaw in this study relates to the measures of daytime sleepiness used for the purpose of matching SAS and non-SAS patients. These authors relied on nocturnal sleep latency (as opposed to daytime Multiple Sleep Latency Tests) and on a 'clinical rating of observed sleepiness obtained from the sleep lab director' to gauge the sleepiness of each of the subjects. These are very problematic measures of daytime sleepiness - nocturnal sleep latency is not, strictly speaking, a measure of daytime sleep tendency, and a non-blind experimenter-offered rating of the sleepiness of the subjects is obviously open to systematic bias. It is interesting to note that MSLT data were available for 7 of the 10 sleepy controls. The mean MSLT latency for these subjects was 6.9 minutes; this is a value outside the range of pathological sleepiness, suggesting that these sleepy controls suffered from less than extreme daytime somnolence. Although no MSLT data were obtained from the SAS patients, an estimate of their probable level of sleepiness may be derived from their mean Apnea Index of 48. Roth et al. (1980) found that for a group of 10 SAS patients with a mean Apnea Index of 50 the average MSLT latency was 1.9 minutes, well within the range of pathological sleepiness. It can thus be concluded with some confidence that the SAS patients studied by Greenberg et al. were much sleepier that the 'sleepy' controls. This less than adequate matching of daytime sleepiness in the SAS and non-SAS patients obviously hinders the ability of this study to eliminate daytime sleepiness as an explanation for any relative performance deficits observed in the SAS patients. Each subject was administered a battery of neuropsychological tests consisting of 4 subtests of the WAIS-R, the Bender, Trail making B, the Purdue Pegboard (right, left, and both hands summed), a letter cancellation test, the controlled oral word association test, and the Wechsler Memory Scale Logical Memory and Figural Memory subtests (both immediate and delayed recall). One-way ANOVA comparisons found the SAS patients to perform significantly more poorly than the 'sleepy' controls on 5 of the 15 measures (Digit Span, Bender, Purdue Pegboard right and left hand, and letter cancellation). The SAS patients performed significantly more poorly than the non-sleepy controls on 3 of the measures (WMS delayed recall of Figures, Purdue Pegboard right and left hand). Interestingly, the sleepy controls and the non-sleepy controls were not found to differ significantly on any of the cognitive measures. This suggests that these sleepy controls were not significantly more sleepy than the healthy controls and/or that traditional neuropsychological measures are not especially sensitive to the effects of moderate daytime sleepiness. Both conclusions seem justifiable. These workers also computed zero-order correlations between 4 measures of nocturnal respiratory disturbance (these 4 measures were derived from apnea data only; hypopneas were not scored and desaturations not associated with apneas were ignored) and the 15 cognitive measures, using data from the 14 SAS patients only. Four of the 60 correlations were significant (a number barely exceeding that expected by chance alone); poorer performance on Block Design and Purdue Pegboard (both hands summed) was significantly predicted by increasing Time Not Breathing and by a lower Lowest Desaturation achieved. It seems possible that the number of significant correlations was limited both by the small number of subjects from which the correlations were computed and by the failure of these workers to quantify desaturations not associated with apneas. Given the above outlined problems with the sleepiness matching procedure, the following conclusion offered by the authors does not seem fully warranted: "This study's main finding is that hypoxemic sleep apnea patients experience neuropsychological dysfunction beyond what can be attributed to the effects of either excessive daytime sleepiness or aging" (p.260). It can in fact only be safely concluded from these findings that pathologically sleepy SAS patients perform more poorly than moderately sleepy non-SAS patients. No judgment can be made concerning the relative contribution of hypoxemia to this difference in performance.

Yesavage et al. (1985) recruited 41 exclusively elderly males (mean age: 69). All subjects were demonstrated through testing to be non-demented. Roughly half of the subjects were recruited through advertisements (the text of which is not described) and the remainder were sleep disorder clinic patients referred by their physicians for unstated reasons. Because the authors report that 73% of these subjects achieved Apnea + Hypopnea Index scores greater than 5, this sample must be considered unrepresentative of elderly males in general, although potentially interesting in the sense that a wide range of apnea activity was probably captured. A battery of neuropsychological tests consisting of the Raven Colored Matrices, the Peabody Picture Vocabulary Test (PPVT), the WAIS-R Digit Symbol subtest, the Benton Visual Retention Test, the Face-hand test, the Bushke list learning test, a test of reading comprehension, the Stroop color naming test, and Trail making parts A and B was administered to each subject and these scores were correlated with Apnea + Hypopnea Index (these workers did not measure oxygen saturation). Five of these 11 zero-order correlations were significant (no effort was made to control for the possible effects of age and education on these correlations): increasing AHI predicted poorer performance on the PPVT, the Raven, the Stroop, Trail making B, and Digit Symbol. Berry et al. (1986a) recruited 46 middle-aged male snorers from nonclinical sources (mean age: 50; range: 30-75) and administered a battery of cognitive tests consisting of the WAIS-R, Wisconsin Card Sort, Hooper Visual Organization Test, Wechsler Memory Scale, Rey-Osterreith Complex Figure, Verbal Fluency, and Finger Tapping. These subjects displayed a wide range of sleep apnea activity, with 13% of the subjects displaying a high level of apnea/hyopopnea activity (AHI≥5). Partial correlations (controlling for age and education) between 3 measures of nocturnal respiratory disturbance and the 12 scores derived from the battery were computed. Ten of these 36 correlations were significant; all indicated a negative relationship between apnea activity and cognitive skill. Number of desaturations $\geq$4% proved to be the most consistent predictor of neuropsychological functioning, correlating significantly (and negatively) with WAIS-R VIQ and PIQ, Verbal Fluency, Wechsler Memory Scale Memory Quotient, Wechsler Memory Scale delayed recall of Logical Stories, and delayed recall of the Rey-Osterreith figure. Apnea + Hypopnea Index also correlated negatively with WAIS-R PIQ; Apnea Index was significantly negatively correlated with WMS Memory Quotient, delayed recall of WMS Logical Stories, and delayed recall of WMS Figures. Analysis of variance results from unpublished data derived from the same study (Berry, 1985/1986) indicate that when these subjects were stratified into age- and education-equivalent groups based on level of apnea/hypopnea activity, the group with a high level of apnea activity performed significantly worse than the group with no apnea/hypopnea activity on 4 measures (WAIS-R PIQ, WMS delayed recall of Logical Stories, delayed recall of Rey Figure, and Verbal Fluency) and significantly worse than the group with a subclinical level of apnea activity on 1 measure (delayed recall of Rey Figure).

In an important, very recent study similar to the present one in many respects, Knight et al. (1987) recruited 27 elderly subjects of both sexes from community sources. All subjects were aged 65 or older (mean age: 76) and were selected without reference to sleep complaints. Potential subjects with known dementia or heart disease were excluded from participation. The subjects were divided into 2 age-equivalent groups based on level of apnea activity (Apnea Index less than 5, n=17; Apnea Index $\geq$5, n=10). Hypopneas were not scored and desaturations not associated with apneas were ignored. A battery of neuropsychological tests similar to those used by previous studies was administered to each subject and the intellectual functioning of the two groups was compared using T-tests. No group differences were found on any of the 14 measures of cognitive skill. Further, when the High AI group was split along the median of apnea activity (i.e., 5 subjects with AI between 5 and 18, and 5 subjects with AI greater than 18), no significant differences between these small subgroups on the neuropsychological measures were found. The authors did derive two (rather limited) measures of oxygen desaturation: mean desaturation during apneas and lowest saturation attained during apneas; and correlated these, AI, and mean apnea duration with the scores derived from the neuropsychological battery. None of these correlations was significant. The authors concluded that an AI score greater than 5 is not predictive of cognitive deficits in an elderly, nonclinical population, and suggested that a higher cutting score for a judgment of 'clinical significance' is required for this population. The authors do not directly discuss or attempt to explain the failure of their correlational analyses to find any of the relationships between nocturnal respiratory dysfunction and cognitive functioning reported by the other studies of nonclinical subjects reviewed above. Two comments must be made concerning the findings of this study. First, their conclusion is warranted although not particularly enlightening. They have demonstrated that by ignoring the wider range of possible respiratory events (i.e., hypopneas), with which sizable desaturations have repeatedly been shown to be associated and which occur with great frequency in older subjects, groups formed with reference to apneas only do not differ in cognitive skill. Apnea Index alone is not a complete measure of the hypoxemic status of these subjects and it therefore cannot be inferred from these findings that multiple nocturnal desaturations are not predictive of cognitive dysfunction. These findings argue persuasively for a grouping strategy that relies on information pertaining to number of desaturations. The application of such a strategy in this study would probably have shifted several subjects from the low group to the high group, and might or might not have resulted in group differences in neuropsychological functioning - with either outcome a more valid test of the effects of desaturation on cognitive functioning would have been performed. A second, related comment concerns the limited nature of the desaturation indices derived by these authors and the resultant limited utility of the correlations computed with those indices. As mentioned above, any desaturation not directly associated with an apnea, no matter how large, was ignored. From the finding of no significant correlations it can therefore only be concluded that apnea-related desaturations, taken in isolation, are not predictive of neuropsychological functioning. Further, the authors made no attempt to quantify the cumulative severity of apnea-related desaturations; they simply noted the average apnea-related drop in saturation for each subject and the lowest saturation achieved by each during an apnea. Thus, a subject with hundreds of exclusively moderately severe desaturations would have scored 'better' on their measures than a subject with only one very large desaturation. Given what is known about the deleterious effects of chronic low-level hypoxemia (to be reviewed in the following section), this is an illogical way to rate the severity of a subject's nocturnal hypoxemia. Clearly, what is needed is a measure reflecting the absolute number of desaturations a subject experiences across the course of a night. It thus remains unknown whether the inclusion of information about the repetitive desaturations associated with hypopneas, and about the cumulative severity of desaturations, would have improved the predictive strength of the relationship between respiratory disturbance and cognitive skill. The present study addressed all of these criticisms through a much more thorough assessment of apneas, hypopneas, and desaturations of varying degrees and durations.

Finally, Klonoff et al. (1987), intending to test the hypothesis that the commonly-reported cognitive deficits of SAS patients are due not to disease-specific etiological factors but instead to situational anxiety and depression secondary to being labeled as suffering from a 'disease', recruited 11 SAS patients scheduled for imminent surgery to treat their nocturnal respiratory disorder and 11 age-matched patients diagnosed with significant heart disease who were scheduled for imminent coronary-bypass surgery. They were administered a wide-ranging battery of neuropsychological tests, similar to those used by the above studies, both before surgery and 3 months post-surgery. T-test comparisons revealed no group differences in cognitive skill before or after surgery. No correlations between indices of nocturnal respiratory disturbance and the measures of intellectual functioning were computed. The authors concluded: "... there were no cognitive changes that were specific to SAS. ... The findings of this study indicate that many of the previously reported cognitive sequelae associated with SAS are situational reactions and coping mechanisms to disease per se and resolve with successful treatment..." (p. 212). These conclusions are not warranted by the data. First, without a control group of SAS patients not scheduled for surgery it is not possible to evaluate whether (as the authors assume) these cognitive data are generalizable to all SAS patients, or whether the pre-surgery test data were adversely affected by anxiety, making the results non-representative of SAS patients in general and applicable only to SAS patients about to undergo major surgery. Second, without a control group of age-matched healthy controls it is not possible to establish whether both SAS patients and patients with serious heart disease suffer from real neuropsychological deficits (perhaps resulting from the common etiological pathway of long-term oxygen insufficiency). A comparison of the two groups' scores post-surgery with data from healthy controls would have controlled for emotional factors and provided an answer to this second unresolved issue.

The results of the above studies are difficult to summarize. As with any relatively young literature, investigators have not yet arrived at a consensus on issues concerning which variables are of most interest, which subjects are of most interest, and which questions should be asked of their data. A few trends are, however, apparent. When the neuropsychological functioning of subjects with high levels of nocturnal respiratory disturbance has been compared to that of subjects with no sleep-disordered breathing or to that of subjects with high levels of sleep-disordered breathing not accompanied by untoward desaturation, significant differences in functioning have been found. The two studies not finding such differences were importantly flawed by either a failure to measure the full range of nocturnal respiratory events or by a failure to use appropriate control groups. Of the three different studies performing appropriate comparisons, at least two have found subjects with high levels of apnea/desaturation activity to perform significantly more poorly on measures of intelligence, short-term memory, attention/concentration, visual-motor integration, and motor efficiency. One study found verbal fluency to be depressed in high AHI subjects. Further, several studies found significant negative correlations between either AHI or meaningful measures of oxygen desaturation and measures of verbal and non-verbal intelligence, verbal and non-verbal short-term memory, attention/concentration, motor efficiency, and visuo-spatial reasoning/organization. No study has as of yet provided the information necessary to settle the question of whether otherwise healthy elderly subjects who experience high levels of desaturation suffer from cognitive deficits relative to their non-apneic peers, no study has directly tested the notion that desaturation predicts cognitive performance in this age group, and no study has as of yet provided data that would allow for an estimate to be made of the relative contributions of desaturation and sleepiness to cognitive deficits. The present study was designed primarily to investigate the first 2 of these 3 issues; an effort to investigate the third issue would be necessary only when and if the results of preliminary studies such as the present one suggested a connection between desaturation and neuropsychological abilities.

Current Thinking on the Etiology of Apnea-related Cognitive Deficits

One of the issues the present study attempted to address concerns the etiology of apnea-related cognitive deficits. Two explanations have been offered for the apparent covariation of nocturnal respiratory disturbance and neuropsychological performance. Brief outlines of those explanations and of findings relevant to them will presented in this section.

Carskadon et al. (1980), among others, suggest that the cognitive deficits associated with severe sleep apnea may be the result of disturbed nocturnal sleep. Recall that research comparing the sleep of control subjects and SAS patients indicates that SAS patients typically experience significantly reduced amounts of either REM or slow wave sleep and significantly increased amounts of light sleep, brief arousals, and shifts between sleep stages. Carskadon et al. conjecture that these disturbances of sleep architecture and continuity affect intellectual performance through the medium of increased daytime sleepiness. This notion has recently been refined by Bonnet (1985; 1986), who has proposed a "sleep continuity" theory of the restorative function of sleep. This theory asserts that it is neither total sleep time nor amounts of specific stages of sleep but rather the experiencing of periods of sleep undisturbed by arousal which determines the restorative value of sleep. Bonnet has suggested that these periods of undisturbed sleep must be at least 10 minutes in duration, and has shown that regular arousals at a rate greater than once per 10 minutes of sleep lead to daytime sleepiness and to cognitive performance decrements very similar to those produced by total sleep deprivation. Because sleep apneics experience sleep fragmentation (caused by periodic pauses in respiration) similar to that which he modeled experimentally in healthy volunteers, Bonnet has suggested that the sleepiness- and performance-related problems seen in patients with sleep apnea may be secondary to sleep disturbance rather than to reduced blood oxygen levels (Bonnet, 1987).

One way to test this idea would entail comparing the neuropsychological performance of two age-matched groups of subjects with equally pathological levels of daytime sleepiness but differing on the presence of high levels of apnea activity. Although such a study has been attempted (Greenberg et al., 1987; see preceding section), a detailed examination of the method used to match the daytime sleepiness of the high and low apnea groups suggested that sleepiness was only partially controlled. Of the 5 measures on which the two groups differed (Digit Span, Letter Cancellation, Purdue Pegboard Right and Left hand, Bender), the first 4 contain 2 of the several task requirements that are sensitive to the lapses of attention attendant upon sleepiness: short term memory and speed of performance (Johnson, 1982). Because the SAS group was probably substantially more sleepy than the control group, the observed group differences on cognitive measures (all in the direction of poorer performance in the SAS subjects) could conceivably have been the result of daytime sleepiness.

The possible relevance of daytime sleepiness to performance deficits in SAS patients has been demonstrated by a study conducted by Bonnet (1986). In this repeated measures study healthy, non-sleep disordered volunteers were subjected to awakenings at regular intervals of 1 minute for two consecutive nights and then one week later to awakenings at intervals of 10 minutes for two consecutive nights. The two conditions modeled the sleep-fragmenting effects of very high and above average numbers of apnea-related arousals (subjects in the 1 minute condition were aroused an average of 134 times across the night, which can be translated into an Apnea Index score of 20; subjects in the 10 minute condition were aroused 34 times - equivalent to an Apnea Index of 5). A sleep latency test and performance tests were administered to the subjects on a baseline morning as well as on the second morning of each arousal condition. The performance tests were not traditional neuropsychological measures but were instead measures known to be particularly sensitive to the effects of sleep fragmentation and sleep deprivation: a reaction time test, a prolonged test of auditory vigilance, and a work-paced, prolonged test of addition. The two experimental conditions each produced significant increases in daytime sleepiness compared to baseline (the 1 minute condition produced a level of MSLT sleepiness within the pathological range - 2.9 minutes, while the 10 minute condition did not - 5.9 minutes). Only the every-minute arousal condition produced significant performance decrements (on Vigilance and Additions); the 10 minute condition showed intermediate but not statistically significant effects on performance. These findings seem to indicate that the sleep fragmentation which would accompany an Apnea Index of 20 or greater results in significant daytime performance decrements, while the sleepiness produced by an Apnea Index of 5 or less is not sufficient, in and of itself, to produce performance decrements even on measures especially sensitive to sleepiness.

In summary, daytime sleepiness resulting from the very fragmented sleep of severe sleep apneics must be considered a likely contributor to the cognitive performance deficits they exhibit. While it is not clear whether the sleepiness resulting from a more moderate level of sleep fragmentation (such as that produced in patients with Apnea Indexes between 5 and 20) has a significant effect on cognitive test performance, it has been shown that fragmentation consistent with an AI of 5 or less does not lead to significant performance decrements. These findings point to the need to control for the effects of daytime sleepiness in any study attempting to validate additional explanations (such as chronic hypoxemia) for observed performance differences between subjects with differing amounts of sleep-disordered breathing. The present study attempted to control for the effects of daytime sleepiness through partial correlations between indices of nocturnal respiratory activity and measures of neuropsychological skill, controlling for amount of napping behavior.

The second explanation for the apparent covariation of nocturnal respiratory disturbance and neuropsychological functioning emphasizes the etiologic importance of the multiple episodes of oxygen desaturation which accompany sleep-disordered breathing. It has been clearly established that subjects with high levels of apnea/hypopnea activity experience higher numbers of desaturations $\geq 4\%$ and $\geq 10\%$ than subjects with both lesser amounts of apnea/hypopnea activity and subjects without apnea/hypopnea activity (cf., Berry et al., 1986b), and it has been shown that the maximum desaturation achieved during apnea/hypopnea events by subjects with high levels of apnea/hypopnea activity is at least twice as great, on average, as that achieved by subjects with lower levels of apnea activity (cf., Block et al., 1979; Dolly and Block, 1982; Sink et al., 1986; McGinty et al., 1982). Evidence establishing a connection between the frequent, severe desaturations experienced by both SAS patients (Findley et al., 1986; Norman et al., 1986;

Greenberg et al., 1987) and middle-aged snorers (Berry et al., 1986a), and neuropsychological performance has begun to accrue. These findings are not surprising, given what is known about the cognitive effects of chronic hypoxemia in other populations. The neuropsychological functioning of one such population, consisting of persons who suffer from chronic obstructive pulmonary disease (COPD), has been relatively well studied.

Grant et al., (1982) administered a battery of tests consisting of the WAIS, the Halstead-Reitan Battery, Trailmaking, the Aphasia Screening Test, and the Logical Story and Drawing subtests of the Wechler Memory Scale (30 minute delayed recall) to very large age-, sex-, and education-matched groups of COPD patients and healthy controls. The COPD patients demonstrated significantly poorer performance on 11 of the 14 measures (the three for which there was no significant difference were: Reitan Rhythm, Aphasia Screening, and delayed recall of Logical Stories). The authors noted that the COPD patients performed especially poorly on tasks demanding flexible thought, ability to think abstractly, visual-motor integration, and motor speed, strength, and coordination. The authors concluded from significant negative correlations between measures of both oxygen saturation and of oxygen transport capability and two ratings of global neuropsychological impairment that "... cerebral disorder in hypoxemic COPD is caused, at least in part, by insufficient oxygenation of brain tissue" (p. 1474).

Prigatano et al. (1983), noting that the COPD patients studied by Grant et al. (1982) typically experienced moderate to severe levels of chronic hypoxemia, wished to determine if COPD patients with only mild levels of chronic hypoxemia suffer from similar neuropsychological deficits relative to healthy controls. They recruited 100 mildly hypoxemic COPD patients and compared their neuropsychological test performance to that of 25 age- and education-equivalent healthy controls. All subjects were administered the Halstead-Reitan Battery, the WAIS, the Wechsler Memory Scale (with both immediate and delayed recall of Stories, Figures, and Paired Associates), the Aphasia Screening Test, Trailmaking, and the Lafayette Repeatable Neuropsychological Test Battery. These mildly hypoxemic COPD patients performed significantly more poorly than the controls on a remarkable 19 of 25 individual measures. Most notably, the COPD patients showed significant deficits on PIQ, all subtests of the Wechsler Memory Scale, Trailmaking B, the Aphasia Screening Test, and the Category, Tactual Performance, and Memory subtests of the Halstead-Reitan. The authors concluded that mildly hypoxemic COPD patients suffer from impairments in memory, abstract reasoning, and speed of performance. Finally, Krop et al. (1973) compared the neuropsychological performance of two groups of COPD patients: one with severe hypoxemia and the other with only mild hypoxemia. A test battery consisting of the WAIS, the Wechsler Memory Scale, the

Bender (both with and without Background Interference), the Facial Recognition Test, and Finger Tapping was administered to 10 severely hypoxemic and 12 mildly hypoxemic COPD patients. The severely hypoxemic patients performed significantly more poorly on both of the Bender-Gestalt scores and both right- and left-hand Finger Tapping. Only left-hand finger tapping remained significantly different between groups after the severely hypoxemic patients were treated for one month with oxygen-enriched air. The results of this study indicate that many of the cognitive deficits demonstrated by severely hypoxemic COPD patients are also present (perhaps to a more moderate degree) in mildly hypoxemic patients, and that deficits in motor speed and visual-motor integration may only result when the degree of chronic hypoxemia experienced is severe.

In summary, some questions concerning the relative contributions of disturbed nocturnal sleep and hypoxemia to the cognitive sequelae of nocturnal respiratory disturbance remain as yet unanswered; the present study attempted to address those questions. Findings concerning the neuropsychological deficits of another chronically hypoxemic population, COPD patients, indicate that many areas of intellectual functioning can be affected, although memory, abstract thinking, perceptual-motor integration, attention, and speed of performance seem particularly vulnerable. The present study measured each of these and several other areas of intellectual functioning in a population expected to demonstrate a wide range of cumulative severity of chronic nocturnal hypoxemia.

Some Methodological and Measurement Issues

The design of the present study allowed for an examination of two methodological questions: 1) Is there a 'first night effect' for indices of nocturnal respiratory disturbance that is similar in magnitude to that which has been demonstrated for EEG indices of nocturnal sleep?, and 2) Which of the many possible ways of measuring and summarizing apnea/hypopnea activity and oxygen desaturation activity are most useful in predicting daytime sequelae?

In 1966, Agnew, Webb, and Williams published the results of a study in which they examined the sleep of 43 subjects who slept in a sleep laboratory for 4 consecutive nights. It was their intention to establish whether the common sleep-research practice of discarding the first night of laboratory sleep as unrepresentative is justified. In brief, they found that this practice is justified; the first night of sleep, in comparison to the second night, was characterized by significantly more awake time, significantly more time spent in Stage 1, and significantly less time spent in Stage REM. Further, they found that the latencies to onset of Stages 4 and REM were significantly delayed, and that the number of shifts between stages was significantly increased. The sleep obtained by these subjects on nights 2-4 was very similar, with no significant differences found among the 3 nights in wakefulness, amounts of time spent in the various stages, and latencies to onset of the various stages. The number of shifts between stages declined significantly on each successive night. The authors concluded that the untoward effects of sleeping in a laboratory for the first time adapt out substantially by the second consecutive night. Several other studies have attempted to replicate these findings (Webb and Campbell, 1979; Hartmann, 1968; Kupfer et al., 1974; Schmidt and Kaelbling, 1971). With the exception of Kupfer et al. (1974), who studied the sleep of psychiatric inpatients, each found significant differences between nights 1 and 2 and each found that these differences had disappeared by the second or third night.

Given the above findings indicating that the measures of sleep obtained during the first night in a laboratory are unrepresentative of typical sleep, it makes sense to wonder if indices of sleep-disordered breathing obtained from only one night of laboratory sleep are similarly unrepresentative. This is not an idle question, as studies designed specifically to investigate one or another aspect of the phenomenon of sleep-disordered breathing rarely (perhaps only 10-15% of the time) perform recordings of their subjects for more than one night. Only four studies to date have attempted to quantify the night-to-night variability of apnea/hypopnea activity. Block et al. (1981) measured the nocturnal respiratory disturbance of 10 post-menopausal women at two different times, each separated by an average of 37 days. These subjects constituted the placebo-treated control group in a study designed to assess whether the administration of progesterone decreases apnea/hypopnea or desaturation activity. The authors derived the following respiratory-related measures: number of apneas, number of hypopneas, number of desaturations $\geq$4%, mean low saturation, mean maximum change in saturation during events, and maximum duration of apneas, hypopneas, and desaturations $\geq$4%. The authors report that there were no significant differences between the two nights for any of these variables. Although these data do establish that measures of apnea activity and desaturation are stable, the stability they establish pertains only to stability between two 'first nights' of measurement. The length of time between measurement nights was so long (roughly 1 month) that the question of whether a habituation to laboratory conditions occurs for indices of nocturnal respiration could not be reasonably answered.

Bliwise et al. (1983) measured apneas and hypopneas in 66 healthy older subjects (mean age: 67; range: 44-88) on two consecutive nights. Oxygen saturation was not measured. Apnea + Hypopnea Index differed significantly on the two nights, showing an average increase of 1.9 from the first to the second night. The correlation between AHI scores on the two nights was .74 ($p < .005$). These authors also examined the nightly variation in number of subjects meeting the criterion of AHI >5. While 11 subjects met this criterion on the first night, twice as many met the criterion on the second night. In only one subject was AHI >5 on night 1 accompanied by an AHI score <5 on night 2. A subsample of 19 subjects were recorded on a third consecutive night; no difference in AHI was found for these subjects between nights 2 and 3. The authors concluded that a single night of polysomnography within healthy older subjects is likely to underestimate the absolute level of respiratory disturbance seen in a second or third night of recording, although night 1 apnea/hypopnea data are clearly significantly predictive of data obtained on subsequent nights. Based on these findings, the authors caution against the occasional practice of inconsistently using different single night findings (that is, using night 1 data from some subjects and night 2 data from others) when attempting to relate individual levels of respiratory disturbance to daytime and other sequelae.

Wittig et al. (1984) reviewed the records of 22 sleep-disorder clinic patients who had been studied on at least two nights separated by no more than 90 days. The authors do not specify the proportion of subjects studied on consecutive nights and they did not perform separate reliability analyses for subjects studied at varying intervals of time. These subjects were divided into two age-equivalent groups based on amount of apnea activity: 11 subjects who experienced more than 100 apnea episodes on night 1 and 11 subjects who experienced less than 100.

Neither hypopneas nor desaturations were measured. Correlations between night 1 and night 2 were performed within each group for the following variables: Apnea Index, mean duration of apneas, and duration of longest apnea. No T-tests comparing the two nights were calculated. All 3 night-to-night correlations were significant within the High Apnea group (correlations ranged from .60 to .88), while 2 of 3 were significant within the 'Low' Apnea group (Apnea Index did not correlate significantly). The results of this study are more easily interpretable for the High Apnea group: subjects with very high numbers of apneas (these subjects demonstrated an average Apnea Index of 54 ± 21) show very high night-to-night reliability for amount of apnea activity regardless of the interval of time that elapses between measurement occasions. The finding that AI is not significantly reliable between nights in the 'low' apnea group is almost impossible to interpret. The authors make no attempt to investigate this finding more fully by separately analyzing data obtained from consecutive nights and data obtained at longer intervals; without such an analysis it is impossible to evaluate the degree of habituation to laboratory conditions which may or may not occur in subjects with less than 100 apneas. Further, the authors make no attempt to draw distinctions between the members of this group and then separately analyze reliability data within subgroups; clearly, many of these low apnea subjects had many apneas and many had very few (the average Apnea Index within this group was 6.5, but S.D. was a very high 4.6). Without making such distinctions it is not possible to determine to whom these findings of night-to-night unreliability can be generalized. The failure of these authors to perform T-test comparisons between nights 1 and 2 is puzzling.

Finally, Kramer and Silva (1986) studied 20 sleep-disorder clinic patients (with complaints of either excessive daytime sleepiness or loud snoring; ages are not given) for two consecutive nights. They quantified both number of apneas and maximum oxygen desaturation and compared nights 1 and 2 data using T-tests. No correlations were calculated. No significant difference between the two nights was found for either variable. However, 45% of these patients demonstrated an increase in AI from night 1 to night 2 of greater than 50%; 20% of the subjects demonstrated an AI <5 on the first night and an AI $\geq$5 on the second night.

In summary, the findings of only 2 of the 4 above studies are relevant to the question of whether a habituation of measures of nocturnal respiratory disturbance occurs across consecutive nights of measurement. The findings of Kramer and Silva (1986) indicate that the night-to-night reliability of AI and desaturation in sleep-disorders clinic patients is relatively high, although membership in a group defined by AI $\geq$5 varies from night 1 to night 2 for 20% of such patients. Bliwise et al. (1983)

found that in healthy older subjects AHI increased significantly from night 1 to night 2, that 17% of subjects not diagnosable as SAS on night 1 became so diagnosable on night 2, and that night 1 AHI was significantly predictive of night 2 AHI. These are important findings and they are in need of replication. Bliwise et al. did not measure oxygen saturation and the night-to-night reliability of this important aspect of sleep-disordered breathing therefore remains unknown for healthy older subjects. The present study attempted to assess the reliability of a wide range of nocturnal respiratory indices in healthy older males.

Finally, the second measurement issue this study attempted to address concerns the question of which of the many possible ways of measuring nocturnal respiratory disturbance are useful in predicting waking deficits. A review of the many studies which have attempted to investigate one or another aspect of sleep-disordered breathing reveals that there is no consensus concerning which variables should be quantified and which should be ignored. Investigators often ignore hypopneas and desaturations without offering justification. Similarly, investigators frequently rely solely on counts of apneas, hypopneas, and desaturations while ignoring the temporal aspects of these (that is, average duration and total amount of time spent in events). Investigators who do measure desaturation often inexplicably fail to offer counts of desaturations of differing degrees of severity and to compute the absolute amount of time spent in desaturations of varying degrees and the average length of desaturation episodes of varying degrees. Finally, investigators rarely if ever calculate either the average saturation change which accompanies apneas and hypopneas or the average duration of the saturation changes accompanying apneas and hypopneas. Clearly, the only way to determine if these and other approaches to the quantification of sleep-disordered breathing are useful or enlightening is to select a homogeneous sample of subjects and examine the intercorrelations among these independent variables and the correlations between those quantifications and other variables of interest. The results of such a study might help future researchers interested in the same population to better allocate the expenditure of limited measurement resources. The present study measured apneas, hypopneas, and desaturations, and derived and analyzed many of the possible ways of summarizing those events.

Statement of the Problem

Sleep Apnea Syndrome is a clinical entity with demonstrated serious consequences. The sleep apneas and related arterial oxygen desaturations frequently observed in SAS patients are thought to play a causal role in the development of associated deficits. Research indicating that sleep apneas and desaturations occur with some frequency in nonclinical samples suggests the hypothesis that specific nonclinical populations at high risk for nocturnal events may suffer from deficits similar to those documented in clinical samples. Convincing evidence supporting this hypothesis in male middle-aged snorers now exists. A review of extant research findings indicates that elderly males comprise a population that is perhaps more at risk for the occurrence of nocturnal respiratory events than any other non-medical population. At present, almost no information is available concerning the concomitants of those events in elderly subjects.

The present study attempted to gather such information. Older males without acute illness were recruited and a comprehensive analysis of their respiratory, oxygen saturation, neuropsychological, sleep/wake, and health status was carried out. Potential relationships between respiratory disturbances and variables known to be disrupted in SAS patients were thus examined in this nonclinical sample.

CHAPTER TWO
METHOD

Subjects

Older males were recruited through newspaper advertisements, posted notices, and phone calls to aging subjects studied previously in the laboratory of W.B. Webb. Participants were required to be male, at least 60 years of age, literate, and in general good health (i.e., self-described as healthy and not under the active care of a physician for acute illness). Potential subjects with a history of head trauma, neurologic or pulmonary disease, alcoholism, or sleep disorder (specifically, narcolepsy or sleep-related nocturnal myoclonus), and those taking medications known to affect sleep (i.e., major and minor tranquilizers, anxiolytics, and anti-depressants), were excluded. Potential subjects who met these criteria were offered an opportunity to participate in a 'sleep study' in which they would complete testing during an evening, sleep overnight in a laboratory with several physiological parameters recorded, and complete a 2 week sleep diary at home, for a payment of $50. Volunteers were scheduled on a first-come, first-serve basis. During recruitment, 19 subjects (chosen on the basis of practical considerations such as laboratory and technician availability and with an eye toward obtaining a wide sub-sample age range) were asked if they would be willing to return to the laboratory for a second night of physiological recording. Fourteen of these subjects agreed and were recorded on two consecutive nights. A total of 40 subjects were studied; one subject who was unable to sleep in the laboratory was dropped. Table 2-1 lists the demographic characteristics of the subjects. The final sample of 39 males had a mean age of 65.8 years and was drawn from a wide cross section of the population, ranging from the retired to the unemployed to university professors. All subjects read and signed informed consent forms and were debriefed at the conclusion of their participation.

Table 2-1. Demographic variables from 39 older males.

	Mean	SD	Range
Age	65.82	4.9	60-83
Education (years)	14.59	2.7	9-20
Weight (lbs.)	178.89	30.3	121-267
Weight:Height Ratio (lbs.:in.)	2.59	0.4	1.7-3.7

Apparatus

During the evening testing all subjects received a blood pressure check, made from a seated position, with a standard hospital cuff. Overnight recordings were made in a quiet, darkened room with the subject sleeping on a standard hospital bed. Electrodes for electroencephalographic recording were mounted in three pairs using sites F2/F8, 02/06, and RE/LE from the international 10/20 system. These electrodes were affixed to the scalp with collodion-soaked gauze dried with an air hose. Three Modified Bipolar EKG leads were attached to the subjects' chests. These 4 EEG and EKG channels were recorded on a Grass Polygraph model 79D at a chart speed of 15 mm/sec. Oral and nasal airflow was measured by a combined thermister affixed to the upper lip. Chest and abdominal movement was measured by impedance pneumography through surface electrodes placed on the lower chest and just above the navel. Arterial oxygen saturation was monitored continuously from a non-invasive earclip attached to the earlobe and analyzed by a Biox 3700 Pulse-Oximeter. These 4 respiratory channels were routed to a strip chart polygraph (Desk Model Physiograph) and recorded at a chart speed of .25 cm/sec.

Measures

Independent Variables

Three groups of independent variables were extracted from the above-described physiological recordings. Respiratory variables (those derived primarily from the airflow thermister and chest/abdominal movement data) included number of apneas and hypopneas. Apneas were scored using the standard criterion of complete cessation of airflow for at least 10 consecutive seconds. Hypopneas were scored using the dual criteria of a reduction in airflow of at least 50% (but less than 100%) and a reduction in blood oxygen saturation of at least 7%. The latter criterion was added when an informal inter-rater reliability check suggested that it was not possible to completely and objectively operationalize guidelines for making a judgment of 50% airflow reduction. The variables derived from counts of numbers of apneas and hypopneas were Apnea Index (#Apneas/Sleep Period Time), Hypopnea Index (#Hypopneas/Sleep Period Time) and Apnea plus Hypopnea Index (#Apneas + #Hypopneas/Sleep Period Time). Oxygen saturation variables (those derived primarily from the continuous recording of arterial oxygen saturation) included Mean Lowest Saturation, Number of Desaturations ≥4%, ≥7%, and ≥10%, and Duration of Desaturations ≥4%, and ≥10%. Mean Lowest Saturation was derived from minute by minute noting of the lowest saturation attained. Those variables reflecting number and duration of desaturations of varying degrees were adjusted for Sleep Period Time. Desaturations were scored regardless of whether or not they were associated with a reduction in the amplitude of breathing. The third group of variables is made up of measures which take into account both respiratory and oxygen saturation information. These include Mean Saturation Change in Apneas and Mean Saturation Change in Hypopneas. The above variables provide complete coverage of all potentially important aspects of nocturnal respiratory activity: number of both types of respiratory events, chronic amount of variability in oxygen saturation, number of desaturations of varying degrees and their duration, and separate measures of the degree of desaturation accompanying apneas and hypopneas.

In an effort to identify any redundancy of measurement within the independent variables (the indices of nocturnal respiratory activity), a correlation matrix containing the 10 variables reflecting apnea activity, hypopnea activity, desaturation associated with apnea and hypopnea activity, and time spent in, and number of, desaturations of varying severity was calculated. Table 2-2 lists the inter-correlations of these independent variables. An examination of this table suggests that two variables, Apnea Index and Mean Saturation Change in Apneas/Hypopneas, are not well predicted by the other variables, manifesting average inter-correlations of only .54 and .60, respectively. The remaining 8 variables are highly inter-correlated. The redundancy of measurement in this subgroup of variables is apparent from the high average correlations within the group (ranging from .82 to .94). Mean Low Saturation stands somewhat apart from this subgroup in that the average correlation of this variable with the other 7 (.82) is relatively low. In the correlational analyses reported in the following chapter, these 3 variables (Mean Low Saturation, Apnea Index, and Mean Saturation Change in Apneas/Hypopneas) will be retained. In addition, Number of Desaturations $\geq$4% will be retained as representative of the 7 remaining highly inter-correlated desaturation measures. All other variables will be ignored.

Table 2-2. Correlations among the 10 measures of nocturnal respiratory activity.

	AI	HI	AHI	LSat	MSatAH	D4	D7	D10	Sec4	Sec10
AI										
HI	.33									
AHI	.65	.93								
LSat	-.47	-.79	-.82							
MSatAH	.52	.45	.56	-.55						
D4	.50	.97	.97	-.83	.51					
D7	.52	.97	.98	-.84	.56	.98				
D10	.61	.87	.94	-.81	.58	.90	.96			
Sec4	.60	.94	.99	-.85	.59	.98	.98	.92		
Sec10	.67	.81	.91	-.78	.62	.84	.92	.98	.88	
Mean Corr.	.54	.72	.81	-.71	.60	.77	.80	.79	.81	.78
Mean Corr. in redundant group.		.90	.93	.82		.92	.94	.91	.93	.87

Legend: AI=Apnea Index; HI=Hypopnea Index; AHI=Apnea + Hypopnea Index; LSat=Mean Low Saturation; MSatAH=Mean Saturation Change in Apneas/Hypopneas; D4=# of desaturations ≥4%; D7=# of desaturations ≥7%; D10=# of desaturations ≥10%; Sec4=Seconds in desaturations ≥4%; Sec10=Seconds in desaturations ≥10%.

Many of the findings to be reported in the next chapter would be more difficult to interpret if the independent variables of interest (nocturnal respiratory activity) were shown to be phenomena with little or limited night-to-night reliability. Such a finding would call into question the as yet prevalent practice of recruiting subjects for only one night of sleep in studies of the relationship between apnea/hypopnea activity and other variables of interest. It is now common practice, in studies of EEG sleep, to obtain several consecutive nights of sleep data from subjects and then discard the first night's data as unrepresentative. This became common practice after it was shown that there are significant and predictable differences between the sleep obtained by subjects on the first night in a sleep laboratory and the sleep obtained on subsequent nights. This "first night effect" is characterized by longer sleep latencies, greater numbers of awakenings, and less time spent in REM sleep compared to other nights. In essence it will be the aim of the following analyses to determine if a similar first night effect exists for nocturnal respiratory activity. Fourteen of the 39 subjects slept for two consecutive nights in the laboratory; all physiological measurements (respiratory and EEG) were repeated on the second night. Correlations and T-tests between the same respiratory variables measured on the two nights will be reported, and these will be compared to the findings of similar analyses conducted with the EEG variables, based on the reasoning that if the reliability of respiratory variables does not substantially exceed that of the EEG variables, a first night effect will have been found.

Table 2-3 lists the Night 1 means and standard deviations for demographic, nocturnal respiratory, and sleep variables from the subsample of subjects who were recorded twice. Also listed for purposes of comparison are the full sample means for the same variables. Although the subsample is clearly representative of the full sample across all demographic and EEG variables, there is evidence indicating that the subsample manifested somewhat higher numbers of apneas, hypopneas, and desaturations. This mild bias is fortuitous because most of the studies for which night-to-night reliability would be an issue make active attempts to recruit subjects who manifest higher than normal levels of respiratory activity (i.e., by selecting subjects on the basis of weight, snoring, complaints of daytime sleepiness, age, etc.).

Table 2-4 lists the Night 1 and Night 2 means from the 14 subjects for all respiratory and sleep variables. An examination of the EEG data suggests that a typical first night effect was found: these subjects took longer to fall asleep, spent more time awake and in light sleep after falling asleep, and spent less time in REM and slow wave sleep on the first night relative to the second. Paired T-tests between Night 1 and Night 2 data were significant for 6 of the 14 EEG variables: Pure Sleep Time, Sleep Efficiency, Sleep Latency, Time % Stage 0, Time % Stage 1, and Time % Stage REM. In contrast, although an examination of the two night means for the respiratory variables suggests a moderate tendency for numbers of respiratory events and desaturations to increase from the first to the second night, no paired T-test comparison was significant for the 10 variables, indicating that these variables are substantially more stable across the first two nights in a laboratory than are EEG variables.

Table 2-3. Means and standard deviations of demographic, first night respiratory, and first night EEG variables from full sample of 39 older males and subsample of 14 subjects who spent two nights in laboratory.

	Sample Mean(SD)	Subsample Mean(SD)
Demographic Variables		
Age	65.8(4.9)	66.1(5.7)
Education	15.6(2.7)	15.4(3.5)
Height:Weight Ratio	2.6(0.4)	2.6(0.5)
Respiratory Variables		
Apnea Index	2.2(3.2)	3.6(3.7)
Hypopnea Index	2.6(6.9)	3.0(4.7)
Ap. + Hypop. Index	4.8(8.6)	6.6(6.6)
Mean Low Saturation	93.0(2.1)	92.7(2.2)
Mean Sat. Change: Ap/Hyp	4.9(3.7)	6.1(4.0)
Number of Desats. ≥4%	8.8(16.7)	11.2(11.6)
Number of Desats. ≥7%	3.6(7.9)	4.8(6.3)
Number of Desats. ≥10%	1.7(3.9)	2.5(3.7)
Seconds in Desats. ≥4%	232.4(380.6)	330.5(321.1)
Seconds in Desats. ≥10%	56.3(123.7)	90.7(137.9)
Sleep Variables		
Pure Sleep Time	325.5(64.6)	347.9(40.2)
Sleep Efficiency Index	.831(0.1)	.849(0.1)
Sleep Latency	11.5(14.0)	12.64(12.8)
Number Stage 0 Periods	1.5(0.9)	1.3(0.7)
Time % Stage 0	13.0(11.0)	11.5(7.6)
Time % Stage 1	3.0(2.3)	2.7(1.3)
Time % Stage 2	55.9(12.2)	58.0(10.2)
Time % Stage 3	1.9(1.0)	2.0(1.0)
Time % Stage 4	13.5(7.4)	13.5(5.8)
Time % Stage REM	12.5(7.6)	12.2(5.5)
Time % Slow Wave Sleep	17.6(8.5)	17.2(6.4)
Latency 1st REM Period	161.1(84.5)	157.0(57.7)
Number of REM Periods	2.7(1.5)	2.8(1.3)
Mean REM Period Length	16.3(9.3)	18.4(9.2)

Table 2-4. Respiratory and sleep variable means for Night 1 and Night 2 in 14 older males.

	Night 1	Night 2
Respiratory Variables		
Apnea Index	3.59	4.17
Hypopnea Index	3.01	3.48
Apnea + Hypopnea Index	6.61	7.65
Mean Low Saturation	92.70	92.19
Mean Sat. Change: Ap/Hyp	6.09	6.43
Number of Desats. ≥4%	11.17	11.68
Number of Desats. ≥7%	4.81	5.86
Number of Desats. ≥10%	2.48	4.23
Seconds in Desats. ≥4%	330.47	354.26
Seconds in Desats. ≥10%	90.70	154.87
Sleep Variables		
Pure Sleep Time	347.93	367.21*
Sleep Efficiency	.849	.906 *
Sleep Latency	12.64	6.36*
Number Stage 0 Periods	1.33	1.35
Time % Stage 0	11.47	6.93*
Time % Stage 1	2.72	1.96*
Time % Stage 2	58.05	57.27
Time % Stage 3	2.01	2.41
Time % Stage 4	13.51	16.43
Time % Stage REM	12.23	14.98*
Time % Slow Wave Sleep	17.17	20.29
Latency 1st REM Period	157.00	129.21
Number of REM Periods	2.78	3.28
Mean REM Period Length	18,41	18.09

*=Significant T-test.

Table 2-5 lists the results of Pearson correlations between Night 1 and Night 2 respiratory and sleep variables. As might be expected, all of the significant correlations are positive. There is a striking preponderance of significant correlations within the group of respiratory variables: 10 of the 10 variables displayed significant night-to-night reliability and 7 of these correlations were strong enough to be significant at the p<.005 level. In contrast, only 8 of the 14 correlations between Night 1 and Night 2 EEG variables were significant, and only one met the p<.005 criterion.

Finally, it can be seen from Table 2-5 that two of the three respiratory variables found, through intercorrelation,

Table 2-5. Results of Pearson correlations between Night 1 and Night 2 respiratory and sleep variables in 14 older males.

	Pearson r
Respiratory Variables	
Apnea Index	.607
Hypopnea Index	.755*
Apnea + Hypopnea Index	.655
Mean Low Saturation	.625
Mean Sat. Change: Ap/Hyp	.886*
Number of Desats. ≥4%	.787*
Number of Desats. ≥7%	.759*
Number of Desats. ≥10%	.862*
Seconds in Desats. ≥4%	.765*
Seconds in Desats. ≥10%	.840*
Sleep Variables	
Pure Sleep Time	.519
Sleep Efficiency	.578
Sleep Latency	.685*
Number Stage 0 Periods	Not Significant
Time % Stage 0	.572
Time % Stage 1	Not Significant
Time % Stage 2	.637
Time % Stage 3	Not Significant
Time % Stage 4	Not Significant
Time % Stage REM	.526
Time % Slow Wave Sleep	Not Significant
Latency 1st REM Period	Not Significant
Number of REM Periods	.639
Mean REM Period Length	.501

*=p<.005.

to be relatively independent of the remaining 7 variables (Apnea Index, Mean Low Saturation, Mean Saturation Change in Apneas/Hypopneas; see Table 2-2) display a relatively low night-to-night reliability. Apnea Index and Mean Low Saturation are the only variables for which reliability did not reach .650. This suggests that their relative independence from other respiratory measures is at least partly attributable to measurement error. Whether this error is systematic (derived, perhaps, from these variables being more sensitive than the others to the effects of sleeping in a laboratory for the first time), or whether apnea activity and chronic fluctuation in oxygen saturation are simply more variable across nights, cannot be determined from the design of the present study. Measurement conducted across several consecutive nights of sleep would be required to settle this issue. One predictable result of this relatively low reliability/high measurement error will be a supression of the correlations between Apnea Index and Mean Low Saturation and any dependent variables of interest. That is, it can be predicted from these reliability data that it will be more difficult to find significant correlations between these two variables and the demographic, health, sleep/wake, and neuropsychological dependent variables than it will be for the other respiratory variables.

In summary, T-test and correlation analyses indicate that nocturnal respiratory activity, measured in a variety of ways, remains stable from the first to the second night in the laboratory. Informal comparison of the reliabilities of respiratory and EEG variables suggests that no "first night effect" of the magnitude observed by this and many other studies for sleep variables exists for indices of nocturnal respiratory activity. These findings provide statistical justification for the single-night design of the present study.

Dependent Variables

The dependent measures fall into three broad classes: measures of health status, measures of sleep/wake status, and measures of neuropsychological status. The measures of health status include height, weight, systolic and diastolic blood pressure, and the Cornell Medical Index (CMI). The CMI (Broadman, et al., 1949) is a wide-ranging, face-valid symptom checklist providing information about past and present physical difficulties. It yields an overall score indicating total number of symptoms endorsed, along with subscale scores for several symptom categories (neurological, pulmonary, and cardiological). These four scores were used in the analyses described below. In addition, subjects' responses to a specific question concerning diagnosis of hypertension were noted and used. Together, the CMI, blood pressure, height, and weight measures provided a broad health screening as well as detailed information concerning health deficits possibly related to apnea/hypopnea activity.

The measures of sleep/wake status include the 2-week Sleep Log, a Sleep Questionnaire, the mean of several Stanford Sleepiness Scale ratings, and overnight EEG. The Sleep Log is a self-monitoring device used extensively in the laboratory of W.B. Webb. Subjects completed the daily Sleep Log during the 2 week period immediately following their visit to the laboratory; return rate was 100%. Variables derived from the Logs include: mean Total Bed Time, mean estimated Sleep Latency, mean estimated number and duration of nocturnal Awakenings, mean number of reports of Daytime Sleepiness, and mean number and duration of Naps.

The Sleep Questionnaire is a largely multiple choice measure which asks for general estimates of a number of sleep-related parameters. Variables derived from the Sleep Questionnaire include: typical Total Bed Time, typical Sleep Latency, typical number and duration of nocturnal Awakenings, typical frequency of feelings of Daytime Sleepiness, and typical number and duration of Naps. The Stanford Sleepiness Scale (SSS) is a frequently-used measure of subjective sleepiness (Hoddes, et al., 1973). It is a 7 point Likert-type scale with each point anchored by statements reflecting increasing degrees of sleepiness (e.g., 1-feel active and vital. ... 7-almost in reverie, sleep onset soon.). The SSS was administered at 1/2 hour intervals beginning with arrival at the laboratory and ending at bedtime. A mean sleepiness rating was derived from these repeated administrations.

The overnight EEG variables were derived from minute-by-minute scoring of the electroencephalographic recordings, using the system of Agnew and Webb (1972) with modification for the scoring of slow wave sleep in older persons (Webb and Dreblow, 1982). A 5-minute combining rule for REM periods was used. Scoring was conducted by a trained and experienced sleep technician. EEG variables include: Sleep Period Time, Pure Sleep Time, Sleep Efficiency Index, Sleep Latency, Number of Stage 0 periods lasting 3 minutes or longer, time % stages 0, 1, 2, 3, 4, and REM, time % Slow Wave Sleep, Latency to 1st REM Period, Number of REM Periods, and Mean REM Period Length.

The measures of neuropsychological status were chosen in an attempt to sample from each of several loosely bounded areas of cognitive skill. These include both verbal and nonverbal intelligence (WAIS-R FSIQ, VIQ, and PIQ), immediate verbal memory (age-corrected Digit Span scale score; Wechsler Memory Scale Paired Associates; and a subscale of the California Verbal Learning Test), delayed verbal memory (30 min. delayed recall of Wechsler Memory Scale Logical Stories; a subscale of the California Verbal Learning Test), remote memory (Memory for Historical Events), immediate nonverbal memory (Spatial Recognition Test), delayed nonverbal memory (30 min. delayed recall of the Wechsler Memory Scale Figures; 30 min. delayed recall of the Rey-Osterrieth Complex Figure), visuo-perceptual/ organizational skills (Hooper Visual Organization Test;

age-corrected Block Design scale score), language ability (Controlled Word Association Test), frontal/self-regulatory skills (Wisconsin Card Sord), and motor functioning (left and right Finger Tapping). Appropriate scores were derived from each of these tests and together they provide both a broad screening of cognitive functioning and a detailed assessment of skills thought to be particularly sensitive to hypoxemia (memory, visual-organizational skills, abstract reasoning, and motor coordination.

Procedure

The following schedule was maintained on the experimental night:

6:00 Sign 2 Informed Consent forms
Stanford Sleepiness Scale
Height and Weight measurement
Blood Pressure measurement
Wechsler Memory Scale (these subtests only: immed. recall of Stories and Drawings; Paired Associates)

6:30 Stanford Sleepiness Scale (interrupt WMS if needed)
WAIS-R (Satz-Mogel Short Form)

6:50 Wechsler Memory Scale (interrupt WAIS-R; 30 min. delayed recall of stories and drawings)

7:00 Stanford Sleepiness Scale (interrupt WAIS-R)

7:30 Stanford Sleepiness Scale (interrupt WAIS-R if necessary)
Rey-Osterreith Figure (Copy and Immediate Recall)
Cornell Medical Index
Sleep Questionnaire
Verbal Fluency

8:00 Stanford Sleepiness Scale
California Verbal Learning Test
Rey-Osterreith Figure (30 min. Delayed Recall)

BREAK (approx. 15 mins.)

8:30 Stanford Sleepiness Scale
California Verbal Learning Test (30 min. del. recall)
Wisconsin Card Sort

9:00 Stanford Sleepiness Scale (interrupt WCS if needed)
Remote Memory Questionnaire

9:30 Stanford Sleepiness Scale (interrupt RMQ if needed)
Spatial Recognition Test
Hooper
Finger Tapping (10 secs.; first right, then left hand - 3 times)
10:00 Stanford Sleepiness Scale
Begin wiring for EEG, Thermister, Resp., Oximeter

11:00 Lights out, begin recording.

6:00 am to 7:00 am wakeup

A sleep technician remained with the subjects throughout the night and the subjects were allowed to determine their own wakeup times.

Statistical Procedures

The primary statistical method utilized in evaluating the present data was correlational. This was considered to be appropriate because of the exploratory nature of the study and because the independent variables of interest do not lend themselves well to experimental manipulation. Other approaches were used in an effort to add confidence, including: 1) partial correlation to separate out variance attibutable to third factors; 2) stratification of the sample by level of desaturation activity and the use of T-tests to evaluate between-group differences; 3) the elimination of redundant independent variables. Non-parametric procedures were utilized where appropriate. The use of multivariate statistics was not feasible due to the limited subjects:variables ratio. Although it must be conceded that a correlational approach carries the burden of possibly producing spurious findings, it is believed that the various additional procedures used lend confidence to the results.

CHAPTER THREE
RESULTS

Incidence of Apnea and Desaturation Activity

Subjects were selected to fulfill several sampling requirements, including male sex, age of at least 60 years, and self report of general good health. Potential subjects were excluded if they reported a history of head trauma, neurologic or pulmonary disease, or alcoholism. Subjects under the active care of a physician for acute illness and those taking medications known to affect sleep (i.e., major and minor tranquilizers, anxiolytics, and anti-depressants) were also excluded from participation. A total of 40 subjects were studied; the data of one subject who was unable to sleep in the laboratory were not included in the analyses reported below. This group of older males had a mean age of 66 years, a mean education level of 14 1/2 years, and a mean weight of approximately 179 pounds.

The respiratory records were divided into 90 minute intervals beginning with the onset of sleep. From a total of 1061 respiratory events scored (hypopneas accompanied by an oxygen desaturation $\geq$7%, plus apneas), 250 (24%) occurred during the first 90 minutes, 207 (19%) occurred during the second 90 minutes, 245 (23%) occurred during the third 90 minutes, 299 (28%) occurred during the fourth 90 minutes, and 60 (6%) occurred during the fifth period. The attenuated number of events beyond the 6th hour of sleep is attributable to the fact that only a small proportion of subjects slept longer than 6 1/2 hours.

Table 3-1 provides a percentage breakdown of respiratory events according to the stages of sleep in which they occurred, along with the relative distribution of time spent in each stage by these subjects. Most events occurred during stage 2 sleep, with the bulk of the remainder being fairly evenly divided between stages 4 and REM. This distribution closely mirrors the proportion of time spent in the various stages and a Goodness of Fit Chi-square analysis of these proportions was not significant (X^2=3.67; p=NS).

Table 3-1. Proportions of apnea/hypopnea events in sleep stages compared with distribution of sleep time among stages.

Sleep Stage	Events	% of Sleep Time
Stage 1	2.83%	3.50%
Stage 2	78.42%	64.34%
Stage 3	1.98%	2.20%
Stage 4	7.07%	15.59%
REM	9.70%	14.38%

Table 3-2 presents a frequency distribution for Apnea + Hypopnea Index (AHI) scores. Seventy-seven percent of the subjects experienced at least one episode of apnea or hypopnea and 20.5% achieved an Apnea + Hypopnea Index (AHI) score $\geq$5. It is apparent from this table, however, that AHI scores are distributed in a highly skewed manner; roughly one-quarter of the subjects experienced no apneas or hypopneas and the great majority experienced very few (less than 3 or 4) such episodes per hour.

Table 3-2. Distribution of number of subjects with varying amounts of apnea + hypopnea activity.

AHI	# Subs.	%	Cumul.%
0	9	23	23
0-1	9	23	46
1-2	5	13	59
2-3	4	10	69
3-4	3	8	77
4-5	1	2.5	79.5
5-6	0	0	79.5
6-7	0	0	79.5
7-8	1	2.5	82
8-9	0	0	82
9-10	0	0	82
10-11	1	2.5	84.5
11-12	0	0	84.5
12-13	0	0	84.5
13-14	2	5	89.5
14-15	1	2.5	92
15-22	1	2.5	94.5
22-29	0	0	94.5
29-36	1	2.5	97
36-43	1	2.5	100

In an effort to determine whether increasing age is related to an increasing incidence of apnea activity, subjects were divided into groups falling above and below the mean sample age (65.8 years) and into 2 groups formed on the basis of AHI scores (AHI less than 5; AHI greater than or equal to 5). Table 3-3 presents the results of this partitioning. An examination of this table suggests that there is little to no relationship between age and incidence of apnea/hypopnea activity within this sample of exclusively older males and a Goodness of Fit Chi-square analysis of these proportions was not significant (X^2=.17; p=NS). Similarly, a T-test comparison of the mean age of subjects

Table 3-3. Incidence of different levels of Apnea + Hypopnea Index scores in 39 older males grouped by age.

Age Group	N	AHI<5	AHI>5
Below Mean Age	22	82%	18%
Above Mean Age	17	76%	23%
Overall	39	80%	20%
Mean AHI(SD)		1.2(1.3)	18.7(10.6)

with AHI scores above and below 5 revealed no significant difference (T=.125; p=NS).

Table 3-4 presents a frequency distribution for numbers of subjects who experienced various amounts of desaturations ≥4% per hour. This too is a highly skewed distribution, indicating that most subjects experienced very few (less than 5 or 6) such desaturations per hour of sleep, while 22.5% of the subjects experienced 9 or more desaturations ≥4% per hour. The 9 subjects with 9 or more desaturations ≥4%/hour averaged 31 episodes per hour; the remaining subjects averaged 2.2 episodes per hour.

Table 3-4. Distribution of number of subjects with varying amounts of desaturations ≥4% per hour.

Desats.	# Subs.	%	Cumul.%	Desats.	# Subs.	%	Cumul.%
0	3	8	8	7-8	1	2.5	75
0-1	6	15.5	23.5	8-9	1	2.5	77.5
1-2	10	26	49.5	9-10	2	5	82.5
2-3	4	10	59.5	10-17	1	2.5	85
3-4	2	5	64.5	17-24	2	5	90
4-5	0	0	64.5	24-31	1	2.5	92.5
5-6	3	8	72.5	31-38	1	2.5	95
6-7	0	0	72.5	38-85	2	5	100

A Pearson correlation matrix relating the demographic variables with the 4 representative nocturnal respiratory indices revealed that while age and education were unrelated to apnea/hypopnea or desaturation activity, weight:height ratio was significantly related to 3 of the 4 indices, indicating that increasing weight predicts increasing desaturation activity.

Table 3-5 presents the results of T-test analyses comparing the above-described 2 groups of subjects (that is, groups formed according to level of desaturation activity: less than 9 desaturations $\geq$4% per hour, or more than 9 such desaturations per hour) on demographic and nocturnal respiratory variables. The cutting score used in the formation of these groups, although somewhat arbitrary, was deemed appropriate because it produced proportions in this sample very similar to those produced by the traditionally-used criterion for clinical significance of AHI$\geq$5, and because it produced a High group with an N large enough for the valid use of small-group T-tests. While there were no significant between-group differences for age and education [T(37)=.05, .04; p=NS], the T-test for weight:height ratio was significant [T(37)=3.5; p=.000], indicating that the High desaturation group had a significantly higher mean weight:height ratio than the Low desaturation group. As would be expected from the method used to form the groups, all indices reflecting number of desaturations (number of Desaturations $\geq$4% and $\geq$10%), severity of desaturations (mean Saturation Change in Apneas and Hypopneas), duration of desaturations (total seconds spent in Desaturations ≥4% and ≥10%), and average nadir of saturation (Mean Low Saturation; recall that this measure was obtained by noting the lowest saturation in each minute of sleep and then averaging across the night), were significantly different between the two groups [T(37)=6.59, 6.58, 5.56, 4.39, 8.69, 7.07, 6.03; all p=.000]. In addition, the between-group differences for Apnea Index and Hypopnea Index were also significant [T(37)=5.93, 5.19; p=.000]. For each of the above respiratory indices the High desaturation group demonstrated a significantly more disordered nocturnal respiratory process than the Low group.

Table 3-5. Means and standard deviations for selected demographic and nocturnal respiratory variables in 39 older males grouped by level of desaturation activity.

	Low Desaturation Group (n=30)	High Desaturation Group (n=9)
Age	65.8(4.9)	65.9(4.8)
Education	14.6(2.9)	14.5(2.1)
Weight:Height Ratio	2.5(0.3)	2.9(0.5)*
Apnea Index	0.9(1.1)	6.2(4.6)*
Hypopnea Index	0.2(0.2)	10.7(11.5)*
Mean Low Saturation	93.8(1.1)	90.3(2.4)*
Mean Sat. Change: Apn.	2.7(3.0)	9.0(2.9)*
Mean Sat. Change: Hyp.	3.6(4.0)	9.6(1.3)*
Number of Desats. ≥4%	2.2(2.2)	31.0(24.4)*
Number of Desats. ≥10%	0.1(0.4)	6.9(5.7)*
Seconds in Desats. ≥4%	63.9(58.8)	794.4(462.2)*
Seconds in Desats. ≥10%	5.5(15.6)	225.3(173.3)*

*=Significant T-test.

In summary, the present sample of 39 males with an average age of 66 years, an average education level of 14 1/2 years, and an average weight of 179 lbs. exhibited a wide range of apnea/hypopnea and desaturation activity. A total of 1061 respiratory events were scored, with 77% of the subjects experiencing at least one apnea or hypopnea and 20% exhibiting a level of apnea/hypopnea activity traditionally considered to be clinically significant. Similarly, 82% of the subjects experienced at least one desaturation $\geq$4% and 22% experienced an average of more than 9 desaturations per hour of sleep. Respiratory events were evenly distributed across the course of the night and they occurred most frequently during Stage 2 sleep. Non-parametric, T-test, and correlational analyses failed to reveal a significant relationship between age and apnea/hypopnea or desaturation activity within this exclusively older sample, while correlational and T-test analyses found weight:height ratio to be significantly and positively related to respiratory activity. When the sample was stratified by level of desaturation activity, subjects with a high number of desaturations had significantly more respiratory events and significantly more severe and long-lasting desaturations than the remaining subjects.

Nocturnal Respiratory and Health Related Variables

Health variables included seated blood pressure readings and several scores derived from the Cornell Medical Index (overall number of symptoms endorsed, as well as number of symptoms endorsed from the respiratory, cardiological, and neurological subscales). Twenty-four Pearson correlations relating these variables to the 4 representative respiratory indices described above resulted in 5 significant correlations (a number greater than would be expected by chance alone). Diastolic blood pressure and number of respiratory and cardiological symptoms endorsed on the Cornell Medical Index (CMI) were unrelated to any of the indices. Table 3-6 lists the remaining variables and the significant correlations found. Systolic blood pressure was significantly positively related to number of desaturations, and was negatively related to Mean Low Saturation. The number of neurological symptoms endorsed on the CMI was positively related to indices reflecting both number of apneas and number of desaturations. Because both age and weight could serve as possible third-variable explanations for the observed significant relationships between Systolic

Table 3-6. Significant ($p<.05$) Pearson correlations between nocturnal respiratory variables and health variables in 39 older males.

	BP Sys[a]	CMI Ov[b]	CMI Neur[c]
Apnea Index			.32
Mean Low Saturation	-.61*		
Mean Sat. Change: Apneas and Hypopneas			
Number of Desats. ≥4%	.59*	.28	.29

[a] BP Sys=Systolic blood pressure.
[b] CMI Ov=Cornell Medical Index - overall score.
[c] CMI Neur=Cornell Medical Index - neurological score.

*=$p<.01$.

blood pressure and the two desaturation measures, partial correlations between these variables, controlling for both age and weight:height ratio, were conducted. Both correlations remained significant at the .05 level, although both were reduced in strength (Systolic BP with Mean Low Saturation = -.30; Systolic BP with # of Desaturations $\geq$4% = .44).

In an effort to further explore the possible relationship between blood pressure and desaturation activity, subjects were asked whether they had ever been diagnosed with hypertension. Thirty-seven percent of those in the Low desaturation group had diagnosed hypertension, while 55% of the subjects in the High desaturation group had diagnosed hypertension. Although there is a trend in these data toward a higher incidence of hypertension in subjects with a higher number of nocturnal desaturations, a Goodness of Fit Chi-square analysis of these frequencies was not significant (X^2=1.25; p=NS).

The subjects were grouped into the previously described levels of desaturation (i.e., above and below 9 desaturations $\geq$4% per hour). Table 3-7 presents the means and standard deviations of the two groups for the health variables. T-test analyses comparing the two groups on these health variables revealed no significant between-group differences: Diastolic BP., T(37)=1.6; Systolic BP., T(37)=1.1; CMI overall, T(37)=0.7; CMI respiratory, T(37)=1.6; CMI cardiological, T(37)=1.2; CMI neurological, T(37)=1.5; all p=NS.

Table 3-7. Means and standard deviations for health related variables in 39 older males grouped by level of desaturation activity.

	Low Desaturation Group	High Desaturation Group
Diastolic BP[a]	126.1(16.9)	139.8(15.8)
Systolic BP	75.9(6.3)	80.7(14.4)
CMI[b] Overall Score	18.1(9.4)	21.2(18.3)
CMI Respiratory Score	1.3(1.4)	0.5(0.7)
CMI Cardiological Score	1.5(1.6)	2.3(2.4)
CMI Neurological Score	0.9(1.2)	1.8(2.2)

[a] BP= blood pressure.
[b] CMI= Cornell Medical Index.

In summary, correlational procedures revealed significant relationships between higher Systolic blood pressure and worsening respiratory indices reflecting number of desaturations. In addition, the number of neurological symptoms endorsed on the CMI was positively related to two of the 4 respiratory indices. The findings pertaining to cardiac functioning are consistent with those of previous workers, but are balanced by the failure of Chi-square analysis to reveal a significant relationship between diagnosis of hypertension and an increased level of desaturation activity and by the failure of T-test procedures to reveal significant between-group differences on the blood pressure variables.

Nocturnal Respiratory and Sleep/Wake Variables

EEG Data

Electroencephalographic variables were recorded overnight for all subjects. Records were scored by a trained, experienced technician who utilized the system of Agnew and Webb (1972) to determine sleep stages. Fourteen representative variables were derived from the sleep stage scoring. Table 3-8 presents the means and standard deviations of these variables for all subjects. Although subjects spent an average of 6 1/2 hours in bed they typically obtained only 5 1/2 hours of sleep. Percentage of wake time and sleep latency are somewhat higher than normal, and percentage of time spent in REM is somewhat lower than normal. These findings are consistent with a typical 'first night effect'.

Table 3-8. Means and standard deviations for representative sleep variables from 39 older males.

	Mean	Standard Deviation
Pure Sleep Time	325.5	64.6
Sleep Efficiency Index	.831	0.1
Sleep Latency	11.5	14.0
Number Stage 0 Periods	1.5	0.9
Time % Stage 0	13.0	11.0
Time % Stage 1	3.0	2.3
Time % Stage 2	55.9	12.2
Time % Stage 3	1.9	1.0
Time % Stage 4	13.5	7.4
Time % Stage REM	12.5	7.6
Time % Slow Wave Sleep	17.6	8.5
Latency 1st REM Period	161.1	84.5
Number of REM Periods	2.7	1.5
Mean REM Period Length	16.3	9.3

Pearson correlations were calculated between the overnight EEG variables and the respiratory variables. Fifteen of the 56 correlations were significant at the $p<.05$ level (9/56 were significant at the $p<.01$ level, numbers greater than would be expected by chance alone). All respiratory indices yielded at least one significant correlation with the EEG variables. Table 3-9 lists the significant correlations.

A complicated pattern of relationships between sleep and respiratory variables emerges from these findings. Assuming, as seems reasonable, that respiratory events act as 'causes' which have effects on sleep, then the following conclusions seem warranted: 1) It is specifically the cumulative number of desaturations, and not the number of 'events' more broadly defined, which has a distorting effect on sleep. This conclusion is based on the facts that neither Apnea Index nor Mean Saturation Change in Apneas/ Hypopneas (MSatAH) was convincingly related to the sleep variables (2/28 correlations were significant) and that neither of these two variables carry any information reflecting the sheer number of desaturations a subject experienced (apneas are scored without reference to an accompanying desaturation and MSatAH could be quite elevated in a subject with only one large apnea- or hypopnea-induced desaturation). In contrast, the 2 indices reflecting number of desaturations (Mean Low Saturation and Number of Desaturations $\geq 4\%$) were impressively related to several

Table 3-9. Significant (p<.05) Pearson correlations between EEG and nocturnal respiratory variables in 39 older males.

	Ap. Index	LoSat	MSatAH	Desats. 4%
PST		.30		
Eff.				
Lat.				
# St.0			.27	
%0				
%1	.31			
%2		-.43*		.48*
%3				
%4		.41*		-.36
%REM		.46*		-.43*
%SW		.42*		-.37*
REM Lat.				
#REMs		.58*		-.50*
REM P.L.		.30		-.34

Legend: Ap. Index=Apnea Index, MSatAH=Mean Saturation Change in Apneas/Hypopneas, LoSat=Mean Low Saturation, Desats. 4%=# of Desaturations ≥4%.

PST=Pure Sleep Time, Eff.=Sleep Efficiency, Lat.=Sleep Latency, # St.0=Number of Stage 0 Episodes, %0= Time % Stage 0, %1=Time % Stage 1, %2=Time % Stage 2, %3=Time % Stage 3, %4=Time % Stage 4, %REM=Time % Stage REM, %SW=Time % in Stages 3+4, REM Lat.=REM Latency, #REMs=Number of REM Periods, REM P.L.=Mean REM Period Length.

*= p<.01.

sleep parameters. 2) The distortion of sleep caused by desaturations is characterized by a reduction of time spent in Stages REM and 4 and a mirroring increase in time spent in Stage 2. This conclusion is based on the myriad negative relationships between desaturation indices and those variables reflecting time spent in stages REM and 4 and the apparently corresponding positive relationships between the same indices and time spent in Stage 2. 3) Desaturations do not bring about an increased amount of awake time, as essentially none of the EEG variables reflecting awakenings (% Stage 0, # of Stage 0 Episodes, Sleep Efficiency Index) was significantly related to respiratory indices. This finding must be interpreted cautiously, however, as the criterion for wakefulness used in this study (at least 31 seconds of wakefulness in a given minute) could not capture shorter arousals. Thus, it remains unknown from these data whether increasing numbers of desaturations lead to an increased number of short arousals. Combining conclusions 2 and 3, it appears that desaturations almost exclusively cause a shift from REM and Stage 4 into 'lighter' sleep (Stage 2) and not into wakefulness as traditionally defined.

Table 3-10 presents the sleep variable means for the subjects grouped by level of desaturation activity. Although these data suggest that the High desaturation group took less time to fall asleep, spent more time in Stage 2, and less time in stages 4 and REM than the Low group, T-test comparisons revealed significant between-group differences on only 2 variables, both relating to REM: Time % Stage REM and Number of REM Periods [T(37)=1.80, p=.04; T(37)=1.95, p=.03]. These findings indicate that the High desaturation group spent a significantly smaller proportion of sleep time in stage REM and manifested a significantly lower number of REM periods than the Low group. These are the T values for the non-significant group comparisons: Pure Sleep Time,

Table 3-10. Means and standard deviations for selected sleep variables from 39 older males grouped by level of desaturation activity.

	Low Desaturation Group (n=30)	High Desaturation Group (n=9)
Pure Sleep Time	328.4(67.0)	316.1(58.5)
Sleep Efficiency Index	.829(0.1)	.840(0.1)
Sleep Latency	13.4(15.4)	5.3(4.5)
Number Stage 0 Episodes	1.5(0.8)	1.4(1.0)
Time % Stage 0	13.0(11.9)	13.0(7.9)
Time % Stage 1	2.9(2.2)	3.4(2.8)
Time % Stage 2	54.4(11.5)	60.9(14.0)
Time % Stage 3	1.8(0.8)	2.1(1.4)
Time % Stage 4	14.0(7.5)	11.9(7.3)
Time % Stage REM	13.7(7.1)	8.6(8.2)*
Time % Slow Wave Sleep	18.2(8.8)	15.5(7.8)
Latency 1st REM Period	161.5(81.3)	160.0(99.8)
Number of REM Periods	2.9(1.4)	1.9(1.6)*
Mean REM Period Length	17.4(9.5)	12.9(8.0)

*=Significant T-test.

T(37)=0.5; Sleep Efficiency Index, T(37)=0.2; Sleep Latency, T(37)=1.5; Number of Stage 0 Episodes, T(37)=0.6; Time % Stage 0, 7(37)=0.0; Time % Stage 1, T(37)=0.5; Time % Stage 2, T(37)=1.4; Time % Stage 3, T(37)=0.6; Time % Stage 4, T(37)=0.7; Time % Slow Wave Sleep, T(37)=0.8; REM Latency, T(37)=0.1; Mean REM Period Length, T(37)=1.3; all p=NS.

In summary, subjects spent an average of 6 1/2 hours in bed and an average of 5 1/2 hours sleeping. EEG data indicate the presence of a typical 'first night effect'. Several sleep variables were found to be significantly correlated with various of the respiratory indices, suggesting that an increasing number of desaturations has a distorting effect on sleep characterized by a reduction of time spent in stages REM and 4 and an increase in time spent in Stage 2. Respiratory indices were not found to be related to amount of awake time, but it remains unknown from these data whether an increased number of desaturations leads to an increased number of short arousals. The above relationships were not consistently reflected in between-group differences when subjects were stratified by level of desaturation activity; however, the High desaturation group was found to have a significantly diminished REM percentage and number of REM periods.

Daytime Sleepiness and Napping Data

The variables to be discussed in this and the following section were taken from 3 sources: the Stanford Sleepiness Scale (SSS), the Sleep Questionnaire (SQ), and the 2-week Sleep Logs. The SSS is a 7 point Likert-type scale with points anchored by statements reflecting increasing degrees of sleepiness (e.g., 1-feel active and vital. ... 7-almost in reverie, sleep onset soon.). The SSS was administered to subjects at 1/2 hour intervals beginning with their arrival at the laboratory and ending at bedtime. An average sleepiness rating was derived from these repeated administrations. The SQ is a largely multiple-choice measure which asks for general estimates of a number of sleep and sleep related parameters (e.g., typical degree of sleepiness felt during the day, typical number and duration of naps taken each week, etc.). The Sleep Log is a device allowing for daily self observation of a number of sleep related variables (e.g., amount of sleep obtained, number and duration of naps taken, etc.). Per-day averages were derived from the 14 days of information provided by each subject.

Six Sleep Log and SQ variables relating to daytime sleepiness and napping behavior, in addition to the mean SSS rating, were correlated with the respiratory variables. Spearman Rank Order correlations were computed where appropriate. Of these 28 correlations, 7 were significant at the $p<.05$ level (2/28 were significant at the $p<.01$ level, numbers greater than would be expected by chance alone). The SSS ratings, the Log and SQ ratings of daytime sleepiness, and the SQ estimates of number of naps typically taken each week were not significantly related to any of the respiratory indices. Table 3-11 lists the significant correlations found. An examination of these correlations suggests that the number of naps and the amount of time spent napping by these subjects is positively related to respiratory indices reflecting number of desaturations and number of apneas.

Table 3-12 lists the means and standard deviations of these daytime sleepiness and napping variables for the subjects grouped by level of desaturation activity. T-test analyses (or, where appropriate, Wilcoxon Rank-Sum tests for two groups) revealed significant between-group differences on 4 of the 7 variables: average minutes napping from both

Table 3-11. Significant (p<.05) Pearson or Spearman correlations between daytime sleepiness/napping and respiratory variables in 39 older males.

	AI	LoSat	MSatAH	D4
Log Naps	.33			.27
Log Np	.33			.36
SQ Np	.48*	-.32		.47*

Legend: Log Naps=Log average # naps reported, Log Np= Log average minutes of napping reported, SQ Np= Sleep Questionnaire typical minutes napping/week.

AI=Apnea Index, LoSat=Mean Low Saturation, D4=# Desats. ≥4%, MSatAH=Mean saturation change in apneas plus hypopneas.

*=p<.01.

the Sleep Log and Sleep Questionnaire, number of naps from the Sleep Log, and rating of daytime sleepiness from the Sleep Log [T(37)=2.34, p=.01; T(37)=2.22, p=.02; T(37)=1.67, p=.05; Z=1.92, p=.03]. These differences indicate that the High desaturation group reported taking significantly more naps and spending significantly more time napping than the Low desaturation group. In addition, the High group members rated themselves as significantly more sleepy during the two week self-observation period than the Low group members. These are the T or Z values for the remaining variables: SSS, Z=0.90; SQ Daytime Sleepiness, Z=0.78; SQ Number of Naps, Z=1.07; all p=NS.

In summary, correlational procedures suggested a positive relationship between respiratory indices reflecting both number of desaturations and number of apneas and

Table 3-12. Means and standard deviations for daytime sleepiness and napping variables in 39 older males grouped by level of desaturation activity.

	Low Desaturation Group (n=30)	High Desaturation Group (n=9)
SSS[a]	2.74(0.8)	3.09(0.8)
Log Dslp[b]	0.72(0.4)	1.23(0.7)*
SQ[c] Dslp	1.90(0.7)	2.11(0.8)
Log Naps[d]	0.47(0.4)	0.74(0.6)*
Log Np[e]	24.28(19.7)	44.12(30.1)*
SQ Naps	3.53(2.5)	4.67(3.0)
SQ Np	3.18(2.6)	7.78(10.6)*

[a] SSS=Stanford Sleepiness Scale.
[b] Dslp=daytime sleepiness rating.
[c] SQ=Sleep Questionnaire.
[d] Naps=number of naps.
[e] Np=minutes napping.

*=Significant T-test.

variables pertaining to amount of napping behavior. The various direct ratings of daytime sleepiness were not reliably related to respiratory variables. The above relationships were reflected in significant between-group differences, indicating that the subjects with a high number of desaturations reported significantly more napping behavior (in terms of both number of naps and minutes napping) than those subjects with low numbers of desaturations.

Subjective Nocturnal Sleep Variables

Both the Sleep Log and the Sleep Questionnaire contain items which ask for estimates of amount of sleep obtained and subjective assessments of sleep latency, number of nocturnal awakenings, and duration of nocturnal awakenings. These 8 variables were correlated (using either Pearson or Spearman correlation) with the respiratory indices. Only 2 of these 32 correlations were significant at the p<.05 level. Because this is not a number of significant correlations appreciably larger than would be expected by chance alone, these correlations will not be discussed.

Table 3-13 lists the means and standard deviations of the subjective nocturnal sleep variables for the subjects grouped by level of desaturation activity. T-test or Wilcoxon Rank-Sum Test for two groups revealed a significant between-group difference on one of the variables: SQ estimate of typical sleep latency (Z=1.97, p=.02), indicating that the High desaturation group reported significantly shorter typical sleep latencies than the Low group. All other group comparisons were nonsignificant: Log Total Bed Time, T(37)=0.82; SQ Total Bed Time, Z=1.17; Log Sleep Latency, T(37)=1.09; Log Number of Awakenings, T(37)=0.18; SQ Number of Awakenings, Z=1.10; Log Minutes Awake, Z=1.20; SQ Minutes Awake, Z=1.18; all p=NS.

In summary, correlational procedures revealed no significant relationships between the subjective nocturnal sleep variables and the respiratory indices. When subjects were grouped according to level of desaturation activity, a significant group difference was found for only one variable, indicating that the High desaturation group reported a significantly shorter average sleep latency on the Sleep Questionnaire than the Low group.

Table 3-13. Means and standard deviations for subjective nocturnal sleep variables in 39 older males grouped by level of desaturation activity.

	Low Desaturation Group (n=30)	High Desaturation Group (n=9)
Log TBT[a]	7.87(0.9)	7.57(0.9)
SQ[b] TBT	7.07(1.3)	7.50(1.0)
Log Lat[c]	18.83(18.4)	11.57(13.6)
SQ Lat	16.80(18.6)	7.44(6.9)*
Log Waks[d]	1.72(0.9)	1.79(1.2)
SQ Waks	2.03(1.3)	2.33(1.0)
Log Aw[e]	18.67(19.2)	17.51(35.7)
SQ Aw	24.07(29.0)	9.67(13.8)

[a] TBT=Total Bed Time.
[b] SQ=Sleep Questionnaire.
[c] Lat=Sleep Latency.
[d] Waks=number of awakenings.
[e] Aw=minutes awake.

*Significant Wilcoxon

Nocturnal Respiratory and Neuropsychological Variables

Eighteen scores were derived from the neuropsychological battery. These include: WAIS-R Full Scale IQ, Performance IQ, Verbal IQ, and Digit Span and Block Design scale scores; Wechsler Memory Scale Paired Associates score, and 30 minute recall of Logical Stories and Figures; Rey-Osterrieth Complex Figure 30 minute recall; Remote Memory (for historical events) number of events recalled; Spatial Recognition Test number of errors; California Verbal Learning Test total number recalled across first five immediate recall trials, and number of items forgotten after 30 minute delay; Verbal Fluency total number of words produced across F, A, and S trials; Wisconsin Card Sort total number of perseverations; Hooper score; and Finger Tapping number of taps in ten seconds with right and left hand.

Pearson correlations were calculated between the above neuropsychological variables and the nocturnal respiratory variables. Because neither age nor education were found to be significantly correlated with any of the respiratory indices (see first section of this chapter), partial correlations were deemed unnecessary. Ten of the 72 correlations were significant at the $p<.05$ level (1 of these was significant at the $p<.01$ level, numbers greater than would be expected by chance alone). All respiratory indices yielded at least one significant correlation with the cognitive variables. Table 3-14 lists the significant correlations.

An examination of these correlations suggests several patterns. First, in every case of a significant correlation, deteriorating respiratory indices are associated with worsening neuropsychological scores. Second, the respiratory variable which carries the most consistent loading on neuropsychological scores is that which reflects a chronically greater fluctuation in oxygen saturation (Mean Low Saturation). Third, there is substantial consistency to the types of cognitive functions which are related to nocturnal respiratory activity. No

Table 3-14. Significant (p<.05) Pearson correlations between neuropsychological and nocturnal respiratory variables in 39 older males.

	AI	LoSat	MSatAH	Desats. 4%
FSIQ		.32		
PIQ		.35		
VIQ		.28		
Digit				
WMS PA				
CVLT Im				
SRT	.43*		.30	
WMS DS				
CVLT D				
WMS DF				
Rey Del				
Remote				
WCS Psv		-.28		
Hooper		.36		-.27
Block		.35		-.31
Fluency				
Finger R				
Finger L				

Legend: FSIQ=WAIS-R Full Scale IQ; PIQ=WAIS-R Performance IQ; VIQ=WAIS-R Verbal IQ; Digit=WAIS-R Digit Span Scale Score; WMS PA=Wechsler Memory Scale Paired Associates; CVLT Im= California Verbal Learning Test Immediate Recall; SRT= Spatial Recognition Test number of errors; WMS DS=Wechsler Memory Scale Delayed Recall of Stories; CVLT D=California Verbal Learning Test number of items forgotten at 30 min. delay; WMS DF=Wechsler Memory Scale Delayed Recall of Figures; Rey D=Rey Figure Delayed Recall; Remote=Remote Memory Questionnaire; WCSPsv=Wisconsin Card Sort number of Perseverations; Hooper=Hooper Test of Visual Organization score; Block=WAIS-R Block Design Scale Score; Fluency= Verbal Fluency Test; Finger R and L=Finger tapping right and left hand.

*=p<.01.

measures tapping immediate or delayed verbal memory, delayed nonverbal memory, remote memory, verbal fluency, or simple motor functioning were found to be related to any of the respiratory indices. However, the IQ measures, the measures tapping visuo-spatial reasoning/organization, the measure of self-regulatory capacity (Wisconsin Card Sort), and the measure of immediate nonverbal memory (Spatial Recognition Test) are significantly correlated with at least one of the three desaturation indices.

The subjects were grouped by level of desaturation activity and T-tests were used to identify possible between-group differences on the various neuropsychological variables. Table 3-15 lists the means and standard deviations of the 2 groups for those variables. Significant differences emerged for 6 of the 18 variables: Full Scale IQ, T(37)=2.32, p=.01; Performance IQ, T(37)=1.98, p=.03; Verbal IQ, T(37)= 2.29, p=.01; Remote Memory, T(37)=2.51, p=.00; Hooper, T(37)= 2.04, p=.02; and Block Design, T(37)=2.42, p=.01. An examination of the group means indicates that for each of these variables the Low desaturation group displayed significantly better functioning than the High desaturation group. Because the two groups did not differ significantly in age or education these cannot be offered as alternative explanations for the between-group differences.

In an effort to determine the clinical (as opposed to statistical) significance of these group differences in functioning, the number of subjects meeting clinical criteria for at least moderate 'impairment' on the WAIS-R, Hooper, Remote Memory Questionnaire, and Block Design tests was determined, and the proportion of subjects with impaired

Table 3-15. Means and standard deviations for neuropsychological variables from 39 older males grouped by level of desaturation activity.

	Low Desaturation Group (n=30)	High Desaturation Group (n=9)
WAIS-R FSIQ	116.7(14.1)	104.2(14.5)*
WAIS-R PIQ	114.5(13.7)	103.5(17.2)*
WAIS-R VIQ	115.3(12.9)	104.1(12.8)*
WAIS-R Digit Span	11.6(2.4)	10.2(3.1)
WMS Paired Assoc.	13.9(3.4)	12.5(3.7)
CVLT Immed. Recall	46.3(11.1)	44.9(15.0)
Spatial Recog. Test	4.2(1.0)	4.8(1.5)
WMS Delayed Stories	12.4(5.3)	11.8(7.1)
CVLT Delayed Recall	0.6(1.0)	0.4(0.7)
WMS Delayed Figures	8.2(4.1)	7.2(3.7)
Rey Delayed Recall	11.0(4.6)	10.3(3.2)
Remote Memory	30.2(8.8)	21.8(8.5)*
WCS # Perseverations	12.9(9.7)	17.2(10.8)
Hooper	24.8(3.1)	21.9(5.2)*
Block Design	9.6(2.3)	7.5(1.9)*
Verbal Fluency	41.8(12.1)	35.1(15.6)
Finger Tap Right	42.1(7.8)	42.2(10.3)
Finger Tap Left	40.4(5.9)	40.2(9.2)

*=Significant T-test.

functioning in the High and Low desaturation groups was compared. A judgment of impairment was made according to the following criteria: a difference between Verbal and Performance IQ of 15 points or greater; a Hooper score of 24 or below; a Remote Memory Questionnaire score of 19 or below (i.e., at least 1 SD below full group mean); an age-corrected Block Design scale score of 7 or below (i.e., at least 1 SD below norm group mean). Results indicate that impairment on the WAIS-R is not differentially associated with desaturation group status (22% in High group, 20% in

Low group), while impairment on the other three measures does appear to be substantially more prevalent in the High group (Hooper: 67% vs. 37%; Remote Memory: 44% vs. 13%; Block Design: 44% vs. 20%).

One issue remains to be addressed with respect to the relationship between nocturnal respiratory activity and neuropsychological functioning. Recall that strong correlations between desaturation activity and various EEG variables reflecting stage distribution were found (see Table 3-10), and that positive correlations were also found between desaturation activity and various indices of daytime sleepiness (i.e., at-home napping behavior). These findings raise the question of whether desaturations have a direct, unmediated effect on cognitive functioning (by, perhaps, altering brain function as a result of multiple time-limited hypoxic episodes), or whether respiratory events have only an indirect effect on cognitive capacity through the increased sleepiness they engender by disrupting the continuity of sleep. Thus, an alternative hypothesis might propose that the relative cognitive deficits observed in subjects with higher levels of respiratory events are the direct result of the multiple short arousals engendered by desaturation events, and that they are not attributable to hypoxia per se. The design of the present study does not allow for a direct test of this alternative hypothesis because, in essence, any index of apnea, hypopnea, or desaturation activity can also be construed as an index of arousal, and vice versa. Thus, it is not possible under the present design to hold hypoxemia constant and evaluate the independent relationship between brief arousal and neuropsychological ability. It is possible, however, to test the perhaps more fundamental assertion that it is daytime sleepiness and not nocturnal hypoxemia which explains the covariation of sleep-disordered breathing and cognitive skill. To do this, partial correlations between the neuropsychological and respiratory variables, controlling for a representative measure of daytime sleepiness, were computed. This approach is based on the reasoning that if respiratory events have an important direct influence on cognitive skill, then controlling for their effect on daytime sleepiness should not substantially diminish their relationship to cognitive functioning. If, however, removal of the variance shared by respiratory and sleepiness variables results in weak or very limited relationships between the respiratory and neuropsychological variables, then the idea that desaturation-induced sleep disruption is a true intervening variable must be entertained.

Table 3-16 presents the findings of partial correlation analyses between selected respiratory and cognitive variables, controlling for the sleepiness variable Amount of time typically spent napping each week (a Sleep Questionnaire variable). This variable was chosen as a control because it displayed the strongest relationships to the respiratory variables (see Table 3-11). Partial correlations were computed only in those instances where simple correlation indicated a significant relationship between a respiratory variable and a cognitive variable (thus, this table is a modified version of Table 3-14).

All of the 10 significant Pearson correlations originally found between the respiratory and cognitive variables remained significant at the .05 level after the relationship between respiratory activity and sleepiness was removed. Thus, these findings clearly indicate that nocturnal respiratory activity (particularly desaturation activity) has an important relationship with cognitive functioning that is independent of daytime sleepiness. Conversely, a correlation matrix between the 5 main measures

Table 3-16. Significant (p<.05) partial correlations between neuropsychological and nocturnal respiratory variables, controlling for EEG Number of REM Periods, in 39 older males.

	MSatAH	AI	LoSat	Desats. 4%
FSIQ			.40*	
PIQ			.42*	
VIQ			.37	
SRT	.29	.39*		
WCS Psv			-.36	
Hooper			.38	-.29
Block			.35	-.33

Legend: FSIQ=WAIS-R Full Scale IQ; PIQ=WAIS-R Performance IQ; VIQ=WAIS-R Verbal IQ; SRT=Spatial Recognition Test number of errors; WCSPsv=Wisconsin Card Sort number of Perseverations; Hooper=Hooper Test of Visual Organization score; Block=WAIS-R Block Design Scale Score.

*=p<.01.

of daytime sleepiness (SSS, # naps from Log and SQ, and average minutes napping from Log and SQ) and the 18 cognitive variables yielded only 3 significant correlations, a number smaller than would be expected by chance alone. This suggests that sleepiness, as measured in this study, is unrelated to neuropsychological functioning in this non-clinical population.

In summary, correlational procedures indicated relationships between nocturnal respiratory indices and measures of verbal and nonverbal intelligence, immediate nonverbal memory, visuo-spatial reasoning/organization, and the ability to shift cognitive set while problem solving. In each case indices reflecting higher numbers of respiratory events and desaturations predicted worsening cognitive scores. Division of subjects by level of desaturation activity indicated that those with a high number of desaturations displayed significant deficits relative to controls on measures of intelligence, remote memory, and visuo-spatial reasoning/organization. An examination of the differential predictive importance of respiratory measures and daytime sleepiness indicated that nocturnal desaturation has a significant relationship with cognitive functioning that is not dependent on its relationship with daytime sleepiness.

CHAPTER FOUR
DISCUSSION

Demographics and Incidence of Nocturnal Respiratory Disorder

The main purpose of the present investigation was to quantify, in a nonclinical population, the relationship between sleep-disordered breathing and variables reflecting the kinds of deficits typically seen in patients with Sleep Apnea Syndrome. The present sample of 39 older males, recruited without reference to sleep or breathing complaints from the community at large, was selected as a nonclinical group likely to display a wide range of sleep-disordered breathing; the selection requirement of general good health insured that subjects with a classic SAS were excluded. Thus, this sample, with a mean age of 66 years and a mean education level of 14 1/2 years, is roughly representative of the nonclinical population of elderly males and it therefore seems valid to examine the incidence rate for apnea/hypopnea activity, the prevalence rate for a clinically significant level of apnea/hypopnea activity, and the concomitants of sleep-disordered breathing as they pertain to that population.

Seventy-seven percent of these subjects experienced at least one episode of apnea or hypopnea and 20% achieved an Apnea + Hypopnea Index (AHI) score ≥ 5. Similar percentages were found for presence, and high numbers, of desaturations $\geq$4%. Only two other studies have reported apnea/hypopnea incidence data derived from relatively healthy, nonclinical elderly males. Carskadon and Dement (1981) found that 88% of elderly males experienced at least one episode of apnea or hypopnea and that 44% achieved AHI scores $\geq$5. These rates are somewhat higher than those found in the present sample; this discrepancy may be attributed to two factors: some of the subjects studied by Carskadon and Dement had prominent complaints about their sleep (such complaints have been shown to predict higher levels of apnea activity in elderly subjects; cf., Ancoli-Israel et al., 1981), and Carskadon and Dement scored hypopneas without requiring a minimum degree of accompanying oxygen desaturation. The present study made use of such a requirement (desaturation of at least 7%) for the purpose of ensuring scoring reliability; logically, such a requirement would lower the number of scorable hypopneas. Smallwood et al. (1983) found that 46% of elderly males achieved AHI scores $\geq$5. This prevalence rate is quite similar to that reported by Carskadon and Dement (1981) and is higher than that found by the present study; this is not surprising as these authors, like Carskadon and Dement, scored hypopneas without referring to the accompanying level of oxygen desaturation.

Thus, the incidence of sleep-disordered breathing in nonclinical elderly males lies between 77 and 88%, and the prevalence of a traditionally-defined 'clinically significant' level of apnea activity lies between 20 and 46%. The lower rates found by this study may be considered more valid as they are based on measures for which at least a modicum of scoring reliability was insured.

Within this exclusively elderly sample, increasing age was not found to significantly predict increasing levels of apnea/hypopnea activity or increasing numbers of desaturations; this finding represents a replication of previous findings derived from comparable samples (Ancoli-Israel et al., 1986; Carskadon and Dement, 1981; McGinty et al., 1982). These data do not, of course, contradict the consistent finding that elderly subjects experience significantly higher numbers of respiratory events than younger subjects. The lack of correlation between age and events within elderly groups may be attributable to a restricted range of age and/or to a possible leveling-off of age-associated increases in respiratory disturbance. Much larger groups of subjects in different older age groups would be required to settle this issue. The only demographic variable found to be significantly related to increasing apnea activity and increasing desaturation within these elderly males was weight:height ratio. This is a relationship found by many previous studies (cf., Bixler et al., 1982; Kales et al., 1982; Block et al., 1980; Block et al., 1979).

When subjects were divided into groups stratified by level of desaturation activity, significant between-group differences were found for all nocturnal respiratory variables. Specifically, the group with a high number of desaturations experienced higher numbers of desaturations of both moderate and severe degree (≥4% and ≥10%), manifested more severe average desaturations in both apneas and hypopneas, and spent greater absolute amounts of time in desaturations of both moderate and severe degree than the group with a low number of desaturations. These differences in number, severity, and duration of desaturation were also reflected in a similar between-group difference on a variable quantifying the average lowest saturation experienced during each minute of sleep. Importantly, the two groups also differed significantly in number of apneas and hypopneas. These findings, although the first of their kind to be reported for nonclinical elderly males, are entirely consistent with reports of similar comparisons made for nonclinical middle-aged snorers (Berry et al., 1986b), nonclinical younger males (Block et al., 1979), and elderly SAS patients (Sink et al., 1986).

It may be concluded from these findings that nonclinical elderly males demonstrate a high incidence of sleep apnea activity and a high prevalence of a 'clinically significant' number of respiratory events. In addition, it seems clear from these findings that a large proportion of elderly males experience many nocturnal oxygen desaturations. With these data in mind it seems justified to attempt to discover waking concomitants of oxygen desaturations in this sample of nonclinical elderly males.

Nocturnal Respiratory and Health Related Variables

Two of the four zero-order correlations computed between respiratory indices and Systolic blood pressure were significant at the .01 level. Both indicated that an increasing amount of desaturation activity predicts higher blood pressure. These correlations remained significant at the .05 level when the effects of age and weight were partialled out. Diastolic blood pressure was not significantly related to respiratory activity. Only one other study to date has correlated direct measures of blood pressure with indices of nocturnal respiratory disorder in a nonclinical sample. Berry et al. (1986b), studying a nonclinical sample of middle-aged male snorers, found a higher number of desaturations of moderate degree ($\geq 4\%$) and a lower Mean Low Saturation to predict higher blood pressure (the correlations found were .37 and -.26, respectively). The comparable partial correlations found in this study were quite similar (.44 and -.30). Although group comparisons on mean Diastolic and Systolic blood pressure and on incidence of diagnosed hypertension failed to reveal significant differences, clear trends toward more disordered cardiac functioning in the high desaturation group were apparent.

Taken together, these findings point to a moderate relationship between increasing blood pressure and an increasing amount of nocturnal oxygen desaturation in nonclinical elderly males. No conclusions about the causal relationship between these phenomena can be drawn from these data. It could plausibly be asserted, for example, that higher waking blood pressure leads to increased nocturnal oxygen desaturation, and that the desaturations themselves have little to no effect on waking cardiac functioning. The most efficient way to test this assertion would take the form of a study in which a sample of older males was provided with a treatment which eliminated desaturations (perhaps nasal CPAP); a comparison of pre- and post-treatment blood pressure would allow for an evaluation of the effect of nocturnal oxygen desaturation on waking blood pressure.

Nocturnal Respiratory and Sleep/Wake Variables

EEG Data

A large number of significant correlations between EEG indices and nocturnal respiratory indices was found. These correlations fall into an easily recognized pattern if one assumes (as seems reasonable) that respiratory events act as causes which have effects on EEG sleep: as the number of arousals subsequent to oxygen desaturation increases, time spent in Stages 4 and REM is decreased and time spent in Stage 2 is increased. Desaturations were found to be unrelated to any of the EEG indices reflecting time spent awake after sleep onset, and so it must be concluded that the sole effect of increasing numbers of desaturation-related arousals is a redistribution of sleep stage amounts away from REM and slow wave sleep and toward lighter sleep. These findings are remarkably consistent with the results of studies examining the effects on sleep of treating sleep-disordered breathing in SAS patients (Weitzman et al., 1980; Roth et al., 1980; Holzer et al., 1985; Issa and Sullivan, 1986). Such treatments have been found to lead directly to increases in time spent in REM and slow wave sleep and to decreases in light sleep and shifts between stages (stage shifts were not quantified in the present study); the results of those studies implicate nocturnal respiratory events as causes of sleep stage redistribution. No previous study has examined the relationship between nocturnal respiratory indices and EEG sleep in nonclinical elderly males; two studies have examined this relationship in younger nonclinical subjects. Each found either very limited relationships (Krieger et al., 1983) or no relationship (Berry et al., 1986b) between EEG sleep and respiration. The most obvious differences between those studies and the present one lie in the older age of the subjects presently studied and in the higher prevalence of large numbers of desaturations in these older subjects. It seems reasonable to conjecture that the sleep of older subjects is more tenuous and more susceptible to disruption and that it is this increased susceptibility to disruption that accounts for the relationships between respiratory events and shifts toward lighter sleep observed in older subjects that are not observed in younger subjects. In fact, the sleep of normal older subjects has been extensively studied and has been frequently compared to that of normal younger subjects. Results of those comparisons almost invariably find that the sleep of older males is characterized by higher numbers of awakenings and increased lability (in the form of both greater numbers of shifts between stages and shorter sustained periods of slow wave sleep and REM sleep; cf., Webb, 1982). Thus, older males are in general more prone to fragmented sleep; the results of the present study indicate, at the very least, that arousals subsequent to desaturations further exacerbate this tendency. It is also consistent with the present data to speculate that age-associated increases in numbers of desaturation-related arousals may be an important cause of the sleep fragmentation commonly observed in older males. A replication of the present findings in another, similarly-aged sample would lend credence to the above speculations. Because brief arousals were not measured independently in the present study, it was not possible to establish directly that these were the medium through which desaturations affected sleep stage distribution, although they are a very likely candidate because previous studies have found brief arousals to almost invariably accompany nocturnal respiratory events (Guilleminault et al., 1976; Roth et al., 1980).

Daytime Sleepiness Variables

When direct and indirect measures of daytime sleepiness were correlated with indices of nocturnal respiratory disturbance, the indirect measures were found to be significantly predicted by measures reflecting number of desaturations and number of apneas. Specifically, the number of minutes these subjects spent in naps during the two week self-observation period and the number of minutes each week they typically spend napping were significantly positively correlated with number of desaturations $\geq$4% and Apnea Index. These correlations were relatively large, ranging as high as .48. The number of naps taken during the two week period was also related to these indices, but somewhat less strongly. The lack of correlation between respiratory indices and direct measures of daytime sleepiness (Stanford Sleepiness Scale administered repeatedly on the laboratory day, and Sleep Questionnaire and Sleep Log ratings of amount of sleepiness experienced each day) probably reflects the imprecision of those measures.

Although several studies have found a relationship between increased sleepiness and increased apnea and desaturation activity in SAS patients (Timms et al., 1985; Roth et al., 1980; Orr et al., 1979; Sink et al., 1986), only two previous studies have investigated these relationships in nonclinical samples. Berry et al. (1986b), studying relatively healthy middle-aged male snorers, found relationships between amount of napping behavior and desaturation and apnea indices very similar to those found in the present sample of elderly males. Thus, the present findings represent a replication of the findings of Berry et al. in a different population of nonclinical males. Knight et al. (1987), studying nonclinical elderly subjects, found no correlation between MSLT data and Apnea Index or desaturation indices, but the measures of desaturation these authors used were extremely limited and did not capture the full range of desaturation activity. Knight et al. did, however, find that elderly subjects with Apnea Index scores above 5 exhibited significantly shorter MSLT latencies than the remaining subjects, and that 30% of the subjects in the high AI group exhibited MSLT latencies within the pathological range (compared to only 6% of those in the low AI group).

When the present subjects were stratified into age-equivalent groups according to level of desaturation activity, the High desaturation group was found to spend significantly more time napping than the Low desaturation group across a variety of subjective measures. These group comparison findings bolster the results of the correlational analyses in pointing to a measurable relationship between nocturnal oxygen desaturation and daytime sleepiness in nonclinical elderly males, and they represent a replication of the above-mentioned findings of Knight et al. (1987) which indicate that nonclinical elderly subjects with high levels of sleep-disordered breathing are significantly more sleepy during the day than controls.

In summary, higher desaturation and apnea indices significantly predicted increased daytime napping behavior in the present sample. The relatively strong relationships between daytime sleepiness and indices of sleep-disordered breathing found in this study, along with the fact that these findings replicate very closely those of Berry et al. (1986b) and Knight et al. (1987) in middle-aged and elderly subjects, respectively, suggests that daytime sleepiness is the aspect of daytime functioning that is most prominently and consistently affected by sleep-disordered breathing in nonclinical populations. These findings provide support for the notion that sleep-disordered breathing in non- clinical populations has daytime consequences that lie on a continuum with those experienced by Sleep Apnea Syndrome patients. Further, these findings suggest that the commonly reported age-associated increases in daytime sleepiness/ napping behavior in males (Tune, 1969; Zepelin, 1973; Gerard, et al., 1978), previously thought to be the inevitable result of 'normal aging', may be directly attributable to age-associated increases in sleep-disordered breathing.

The most obvious etiologic explanation for the observed connection between desaturation and daytime sleepiness is that desaturations cause a disruption of nocturnal sleep which then leads to increased sleep pressure during the day. Findings reviewed in the previous section indicate that desaturation-related arousals distort nocturnal sleep in predictable ways (by lowering time in slow wave and REM sleep and increasing time in lighter sleep). However, desaturations did not predict increased wakefulness (as traditionally scored) at night and they did not predict significant group differences on EEG variables reflecting amount of nocturnal wakefulness. These EEG findings, together with the daytime sleepiness findings, lend credence to the 'sleep continuity' theory of the restorative nature of sleep (Bonnet, 1985; Bonnet, 1986), which states that periodic disturbances of sleep predict increased daytime sleepiness even when total sleep time is preserved (as in the present study). Thus, it may be concluded from these data that the frequent arousals which accompany high numbers of nocturnal desaturations render the sleep obtained relatively non-restorative and lead to compensatory daytime sleeping. It is of course possible to assert that oxygen insufficiency, in and of itself, affects daytime sleepiness in a direct but as yet unknown way. Future research, to investigate this question of etiology, must include a measure of brief arousal. With a measure of brief arousal in hand, the relative power of arousals and desaturations in predicting daytime sleepiness could thus be ascertained.

Nocturnal Respiratory and Neuropsychological Variables

A high number of significant zero-order correlations between indices of nocturnal respiratory disorder and the measures of neuropsychological functioning were found. No measures tapping immediate or delayed verbal memory, delayed nonverbal memory, remote memory, verbal fluency, or simple motor speed were found to be related to any of the respiratory indices. However, the IQ measures, the measure tapping immediate nonverbal memory (Spatial Recognition Test), the measures tapping visuo-spatial reasoning/ organization (Hooper and Block Design), and the measure of cognitive flexibility/self-regulation (Wisconsin Card Sort), all correlated significantly with at least one of the 4 respiratory indices. These correlations were generally of moderate size, ranging from .27 to .43. In every case of a significant correlation, deteriorating respiratory indices were associated with worsening neuropsychological scores. One respiratory index carried a particularly consistent loading on neuropsychological scores: Mean Low Saturation. Because neither age nor education was found to be significantly correlated with any of the respiratory indices, these cannot be offered as alternative explanations for the present findings.

When the subjects were grouped by level of desaturation activity, significant between-group differences were found for 6 of the 18 variables. These included Full Scale IQ, Performance IQ, Verbal IQ, Hooper, Block Design, and Remote Memory. For each of these variables, the High Desaturation group performed significantly worse than the Low Desaturation group. Because these groups did not differ significantly in age or amount of education, these cannot be offered as alternative explanations for the group differences. An informal examination of the clinical significance of the lower neuropsychological scores in the

High desaturation group suggested that clinical impairment was much more prevalent in the areas of Remote Memory and visuo-spatial reasoning/organization.

To summarize, worsening desaturation indices were found to predict lower scores on measures tapping IQ, visuo-spatial reasoning, immediate nonverbal memory, and cognitive flexibility. The group with a high level of desaturation activity was found to perform significantly more poorly than subjects with lower amounts of desaturation activity on measures tapping IQ, visuo-spatial reasoning, and remote memory. Only two previous studies have examined the neuropsychological concomitants of sleep-disordered breathing in nonclinical samples. Berry et al. (1986a), studying middle-aged male snorers, found increasing numbers of desaturations to significantly predict lower scores on tests tapping IQ, delayed verbal and nonverbal memory, and verbal fluency. Further, they found subjects with AHI scores ≥ 5 to perform significantly more poorly than subjects with lower levels of apnea activity on measures of Performance IQ, delayed verbal and nonverbal memory, and verbal fluency. Thus, the present study represents a general replication (in a different population) of the Berry et al. finding that 1) increasing desaturation predicts worsening intellectual functioning across a variety of cognitive skills in nonclinical subjects, and 2) nonclinical subjects with a high level of sleep-disordered breathing perform significantly more poorly than subjects with lower amounts of apnea across a variety of cognitive skills. In addition, the present study specifically replicates the Berry et al. findings concerning measures of IQ and nonverbal memory; these appear to be especially sensitive to the effects of hypoxemia in nonclinical samples, regardless of age. Knight et al. (1987), studying nonclinical elderly subjects, found no differences in neuropsychological functioning between groups falling above and below the criterion of $AI \geq 5$, and they found no significant correlations between respiratory activity and cognitive scores. Recall that these authors did not score hypopneas and that they ignored all desaturations not immediately associated with apneas. From the findings of the present study, which indicate that a chronically lower level of saturation is the best predictor of cognitive scores in this population, it would appear that Knight et al. failed to measure just those aspects of respiratory disturbance which are most related to neuropsychological functioning.

Because it has been suggested that daytime sleepiness and not hypoxemia is the relevant cause of the performance deficits typically observed in subjects with high numbers of nocturnal desaturations (Bonnet, 1987), an effort was made in the present study to control statistically for the effects of sleepiness so that the true strength of the relationship between desaturation and cognitive scores could be ascertained. When daytime sleepiness was removed from the correlations between respiratory and cognitive measures, all correlations remained significant at the .05 level. This indicates that hypoxemia must be considered an important contributor to the poorer neuropsychological functioning of elderly subjects who experience desaturation events. Taking a somewhat wider perspective, the present findings add to the growing evidence that even relatively mild levels of chronic hypoxemia have demonstrable effects on intellectual ability (cf., Prigatano et al., 1983; Krop et al., 1973).

The Night-to-Night Consistency of Nocturnal Respiratory Activity

Fourteen of the present subjects underwent two consecutive nights of physiological measurement. This subsample was representative of the full sample across all demographic and EEG variables; the subsample did, however, manifest somewhat higher average levels of apnea, hypopnea, and desaturation in comparison to the full sample. This can be considered a fortuitous bias because most studies of the concomitants of sleep apnea activity make active attempts to recruit subjects who manifest higher than normal levels of respiratory activity. Thus, reliability estimates from this subsample will be more validly generalizable to future work in this area than would reliability estimates derived from a subsample of subjects manifesting lower than usual levels of apnea activity.

T-test comparisons between Night 1 and Night 2 means for the respiratory variables revealed no significant differences, although an examination of the means suggested a moderate tendency for numbers of respiratory events and desaturations to increase from the first to the second night. A similar analysis conducted with the EEG data revealed significant between-night differences on 6 of the 14 variables. These differences indicated that a typical 'first night effect' occurred: subjects took longer to fall asleep, spent more time awake and in light sleep, and spent less time in Stage REM on the first night relative to the second. These findings indicate that respiratory and desaturation variables are substantially more stable across the first two nights in a laboratory than are EEG variables.

When respiratory indices derived from the first night were correlated with their Night 2 counterparts, significant night-to-night reliability was demonstrated for all of the variables. The significant correlations ranged from .61 to .89, with an approximate average of .73. Seven of these 10 significant correlations were strong enough to be significant at the very conservative $p<.005$ level. In contrast, only 8 of the 14 EEG variables demonstrated significant night-to-night reliability. These correlations ranged from .50 to .68, with an approximate average of .58; only one of these EEG reliabilities was significant at the $p<.005$ level.

In summary, T-test and correlation analyses indicate that nocturnal respiratory activity, measured in a variety of ways, remains stable from the first to the second night in the laboratory. Informal comparison of the reliabilities of respiratory and EEG variables suggests that no "first night effect" of the magnitude observed by this and many other studies for sleep variables exists for indices of nocturnal respiratory disturbance.

Only two previous studies have adequately investigated the night-to-night reliability of respiratory indices. Bliwise et al. (1983) measured apneas and hypopneas (but not desaturations) in healthy older subjects on two consecutive nights. These authors found AHI to be significantly reliable across the two nights (correlation= .74). However, they found Apnea + Hypopnea Index to increase significantly from the first to the second night. The average increase was 1.9; in the present study AHI increased an average of 1.0 on the second night. This somewhat discrepant finding may be attributable to the fact that the present study made an attempt to insure scoring reliability for hypopneas by including a minimum desaturation requirement. Any successful attempt to improve scoring reliability would be expected to reduce unexplained variance and improve test-retest reliability. Kramer and Silva (1986), studying clinical patients, found no significant night 1-night 2 differences for number of apneas or maximum oxygen desaturation. However, they, like Bliwise et al. (1983), emphasized that Apnea Index increased somewhat from the first to the second night in roughly half of their subjects.

From the present data it can only be concluded with confidence that no "first night effect" of the magnitude seen in EEG variables exists for respiratory variables in nonclinical elderly males. Stated another way, these data indicate that if a habituation to laboratory conditions occurs for respiratory variables, it does not occur to a significant degree by the end of the second night. It can be concluded tentatively that attaching a desaturation requirement to the definition of 'hypopnea' lowers the night-to-night variation in this index. Future research should include several consecutive nights of respiratory and desaturation measurement. A comparison of each succeeding night's data will allow for a judgment to be made about whether and when habituation occurs. The findings of the present study, indicating that Apnea + Hypopnea Index tends to increase from the first to the second night, suggest that clinical diagnoses of SAS based on only one night of data probably suffer from a moderate false-negative rate.

Conclusions

The present study has demonstrated that sleep-disordered breathing is a reliable phenomenon which occurs in a very high proportion of healthy elderly males. Further, it has been shown that 20% of such subjects experience what has come to be regarded as a very high number of respiratory events each night. The correlational procedures used in this study indicate that cardiological, daytime sleepiness, nocturnal sleep, and neuropsychological concomitants analogous to those found in SAS patients are also found in subjects who do not meet clinical criteria for SAS. These findings of a linear relationship indicate that sleep-disordered breathing can carry pathological consequences at levels lower than the 'disease' threshold commonly accepted in the literature. It seems clear from the present findings that the implicit idea often encountered in the literature, which states that nocturnal oxygen desaturation is a benign process until it reaches some threshold of "clinical significance," must be discarded in favor of efforts to investigate whether the pathological consequences of sleep-disordered breathing in nonclinical subjects can be reversed through treatment.

APPENDIX
RAW DATA TABLES

List of variables set out in Table A-1.

Var. 1) Age
Var. 2) Education
Var. 3) Height (inches)
Var. 4) Weight
Var. 5) Weight:Height Ratio
Var. 6) Blood pressure: Diastolic
Var. 7) Blood pressure: Systolic
Var. 8) Cornell Medical Index: Overall score
Var. 9) Cornell Medical Index: Respiratory subscale
Var.10) Cornell Medical Index: Cardiological subscale
Var.11) Cornell Medical Index: Neurological subscale
Var.12) Diagnosis of Hypertension? (1=yes; 0=no)

Table A-1. Demographic and medical variables from 39 older males.

ID.#	1	2	3	4	5	6	7	8	9	10	11	12
1	73	12	73	175	2.40	134	74	17	03	00	00	00
2	65	14	72	230	3.19	150	75	15	00	00	02	00
3	66	16	72	267	3.71	145	69	19	00	02	00	01
4	65	18	72	192	2.67	121	65	11	00	02	01	01
5	68	18	67	155	2.31	145	70	14	01	02	01	01
6	72	16	66	155	2.35	118	72	12	00	00	00	00
7	70	16	66	160	2.42	150	80	35	01	03	03	01
8	65	12	69	200	2.89	124	78	06	00	00	00	01
9	67	18	71	225	3.17	134	78	16	01	00	02	00
10	63	11	67	155	2.31	134	80	12	00	03	00	0
11	61	12	69	190	2.75	125	68	25	01	01	03	1
12	65	18	68	152	2.23	119	73	22	02	04	00	0
13	76	15	68	190	2.79	150	98	63	02	06	07	0
14	60	16	67	165	2.46	100	62	31	04	00	00	1
15	66	14	72	121	1.68	109	73	25	00	00	01	0
16	63	12	70	184	2.63	116	68	23	00	00	00	0
17	68	20	67	150	2.24	104	70	19	00	01	01	0
18	62	12	67	175	2.61	160	82	07	01	02	00	0
19	66	17	68	165	2.43	108	78	08	01	02	00	0
20	70	12	69	187	2.71	138	82	09	00	01	00	1
21	62	12	70	165	2.36	110	78	16	02	00	00	0
22	69	15	72	185	2.57	150	84	11	00	01	01	0
23	62	12	60	200	3.33	140	100	27	00	04	03	1
24	68	13	64	150	2.34	128	68	03	00	00	00	1
25	63	13	72	196	2.72	130	82	19	01	00	04	0
26	65	13	66	130	1.97	120	72	14	05	03	00	0
27	60	15	72	200	2.78	122	67	28	01	05	01	0
28	63	15	66	180	2.73	115	70	23	01	02	01	0
29	61	16	69	150	2.17	130	70	13	01	01	03	1
30	67	17	72	207	2.87	116	76	10	01	00	00	0
32	60	14	72	180	2.50	160	72	07	00	01	00	0
33	61	12	69	248	3.59	155	80	33	01	06	02	1
34	72	15	72	201	2.79	135	90	34	04	01	03	1
35	63	20	67	155	2.31	120	70	09	01	02	01	1
36	83	09	69	144	2.09	114	76	20	02	00	00	0
37	70	14	72	160	2.22	135	91	07	02	00	01	0
38	61	13	71	190	2.68	126	80	13	00	03	00	1
39	63	20	69	165	2.39	122	64	13	02	01	00	0
40	63	12	68	178	2.62	150	71	44	03	06	02	1

List of variables set out in Table A-2.

Var. 1) SQ - average total bed time
Var. 2) SQ - amount of sleep (about enough=1, other=2)
Var. 3) SQ - #naps/week
Var. 4) SQ - #hours napping/week
Var. 5) SQ - average # of awakenings/night
Var. 6) SQ - #minutes spent in awakenings/night
Var. 7) SQ - average sleep latency
Var. 8) SQ - is sleep light or deep? (very light=3)
Var. 9) SQ - feel tired due to poor sleep? (never=1)
Var.10) SQ - mean Stanford Sleepiness Scale rating

Table A-2. Sleep Questionnaire and Stanford Sleepiness Scale data from 39 older males.

ID.#	1	2	3	4	5	6	7	8	9	10
1	10.0	1	5	02	1	10	10	1	1	4.89
2	08.5	2	7	10	3	10	10	2	1	4.37
3	06.0	1	3	05	3	03	03	2	2	4.12
4	07.5	1	1	01	1	10	10	2	2	3.13
5	08.0	1	5	06	2	10	10	1	2	3.25
6	09.0	1	7	07	2	80	10	1	1	3.43
7	05.5	1	2	01	2	03	10	1	2	3.00
8	08.0	1	0	00	1	03	03	1	1	1.75
9	08.5	1	7	07	3	10	10	1	2	3.62
10	08.0	1	2	02	2	10	10	3	2	3.25
11	05.0	2	3	01	4	45	23	3	2	2.17
12	07.0	2	2	01	1	03	03	1	2	2.71
13	06.0	2	9	35	3	45	23	2	3	2.57
14	07.0	1	9	07	3	03	03	1	3	2.71
15	04.0	1	6	06	3	03	10	3	2	2.43
16	08.0	1	4	04	1	03	10	1	2	1.57
17	08.5	1	2	02	3	03	10	1	1	3.37
18	07.0	1	2	04	1	10	03	1	2	2.63
19	08.0	1	4	01	1	03	10	1	1	2.37
20	07.0	2	2	03	2	45	23	1	1	2.75
21	08.0	1	4	02	2	45	10	3	2	1.00
22	05.5	1	3	02	1	03	10	3	1	2.14
23	08.5	1	5	06	2	03	03	3	2	2.43
24	07.5	1	0	00	0	00	00	1	2	2.43
25	05.5	1	2	04	1	80	23	1	2	2.57
26	06.5	2	7	04	5	80	80	3	2	2.37
27	05.5	2	1	01	5	80	80	3	3	3.33
28	07.5	1	6	08	1	03	03	1	2	3.00
29	07.0	1	7	04	0	03	10	1	2	3.00
30	07.0	1	1	01	3	03	05	1	1	2.00
32	08.0	2	8	03	2	03	03	2	3	3.50
33	08.0	1	4	04	3	10	10	1	3	3.13
34	07.5	1	0	00	2	10	23	1	2	3.00
35	07.0	1	5	02	3	23	10	3	3	3.86
36	07.0	1	0	00	2	23	23	3	1	1.43
37	08.0	1	2	.5	0	00	23	1	2	2.57
38	06.5	1	7	07	2	45	23	2	2	3.43
39	06.0	1	2	08	2	03	05	1	2	1.57
40	05.0	2	2	04	4	80	23	3	4	3.28

List of variables set out in Table A-3.

Var. 1) average daytime sleepiness rating (very sleepy=3)
Var. 2) average #naps/day
Var. 3) average sleep latency
Var. 4) average #awakenings/night
Var. 5) average minutes awake/night
Var. 6) average minutes napping/day
Var. 7) average total bed time

Table A-3. Two-week Sleep Log data from 39 older males.

ID.#	Var. 1	Var. 2	Var. 3	Var. 4	Var. 5	Var. 6	Var. 7
1	0.86	0.43	17.30	0.64	005.21	07.50	10.34
2	2.14	0.78	08.21	2.43	008.43	57.85	08.34
3	1.75	0.55	04.00	3.00	005.00	42.86	06.00
4	0.28	0.21	12.50	3.71	037.00	08.57	07.75
5	1.57	0.78	12.50	1.21	012.28	82.14	08.46
6	0.71	0.78	17.50	1.21	040.57	39.64	09.07
7	0.50	0.07	27.14	1.14	019.92	02.14	07.57
8	0.07	0.00	07.36	1.28	004.50	00.00	08.46
9	0.50	0.71	22.86	2.14	052.36	28.93	09.05
10	0.92	0.38	15.00	2.54	012.46	21.92	07.60
11	1.36	1.00	14.28	2.21	087.36	18.93	08.64
12	1.00	0.07	02.43	1.43	002.57	02.14	06.89
13	1.00	2.07	46.78	2.28	112.21	97.14	08.18
14	1.08	1.58	03.83	3.17	020.67	45.83	06.98
15	0.21	0.57	09.36	2.07	013.86	37.64	06.77
16	0.64	0.64	16.93	1.36	015.21	17.86	07.57
17	0.28	0.28	09.86	3.14	012.64	15.00	07.98
18	0.86	0.43	07.36	2.43	005.71	35.71	07.86
19	0.14	0.21	03.57	0.07	000.71	02.50	08.80
20	0.14	0.43	09.28	0.64	003.71	20.71	07.82
21	0.43	0.14	13.57	1.86	013.21	10.71	08.11
22	0.43	0.00	08.93	1.00	006.64	00.00	07.02
23	0.14	0.07	05.00	0.00	000.00	08.57	08.21
24	0.43	0.28	03.14	0.28	001.07	25.71	06.64
25	0.86	0.43	34.64	0.57	010.14	71.78	05.98
26	0.71	0.86	37.50	1.93	052.93	43.93	08.71
27	1.00	0.64	46.07	1.86	020.50	43.93	07.80
28	1.14	0.57	07.07	1.93	015.43	36.78	08.18
29	1.07	1.07	09.36	1.93	004.43	49.64	07.07
30	0.50	0.28	10.00	3.00	003.00	17.14	07.00
32	1.93	1.14	04.50	0.93	005.64	22.86	07.36
33	1.65	0.71	10.00	3.00	010.00	42.86	08.00
34	0.00	0.07	18.21	1.00	007.21	04.28	08.14
35	1.00	0.86	13.57	3.57	037.36	35.71	06.86
36	1.00	0.00	20.71	1.00	009.00	00.00	07.86
37	0.93	0.28	21.07	0.14	001.43	02.86	08.14
38	1.14	0.71	23.28	1.71	017.43	44.57	08.43
39	0.86	0.43	14.28	1.57	009.00	53.57	05.82
40	1.57	0.14	99.99	2.43	020.85	25.71	09.25

List of variables set out in Table A-4.

Var. 1) Time in bed
Var. 2) Pure sleep time
Var. 3) Sleep period time
Var. 4) Sleep efficiency
Var. 5) Sleep latency
Var. 6) Number of awakenings
Var. 7) % stage 0
Var. 8) % stage 1
Var. 9) % stage 2
Var.10) % stage 3
Var.11) % stage 4
Var.12) % stage REM

Table A-4. EEG variables from 39 older males (first night only).

ID	1	2	3	4	5	6	7	8	9	10	11	12
1	411	390	408	.948	02	1.62	04.41	01.96	68.13	2.69	12.50	10.29
2	427	380	410	.889	15	1.02	07.37	03.41	70.00	3.17	06.58	09.51
3	242	220	235	.909	07	0.25	06.38	01.70	91.91	0.00	00.00	00.00
4	382	353	378	.924	03	1.59	06.61	02.64	60.05	1.05	11.64	17.98
5	413	387	406	.937	07	0.59	04.67	00.98	54.67	2.21	23.39	14.03
6	406	380	398	.935	07	1.05	04.52	01.75	52.76	3.51	17.83	19.59
7	276	143	218	.518	44	4.13	34.40	09.17	56.42	0.00	00.00	00.00
8	434	396	432	.912	02	0.97	08.33	03.00	49.07	3.24	18.28	18.05
9	389	329	382	.845	06	2.51	13.87	02.35	52.87	1.57	09.42	19.89
10	409	393	401	.960	08	0.90	01.99	00.74	60.84	2.24	09.47	24.68
11	371	281	334	.757	03	1.44	15.86	04.49	38.02	2.39	18.56	20.65
12	404	372	397	.920	05	0.91	06.29	01.25	62.72	1.51	11.08	17.12
13	350	251	313	.717	07	3.26	19.80	10.22	58.46	3.83	07.66	00.00
14	411	378	408	.919	02	1.76	07.35	02.45	64.70	1.71	12.74	11.02
15	350	301	344	.860	05	1.60	12.50	02.61	58.43	1.74	16.56	08.13
16	414	399	412	.963	02	1.02	03.15	00.48	62.37	1.94	12.62	19.41
17	427	401	417	.939	10	0.72	03.83	01.43	79.85	1.19	03.59	10.07
18	363	253	353	.696	04	2.89	28.32	05.94	57.79	1.41	06.51	00.00
19	406	316	331	.778	21	0.91	04.53	01.51	74.62	0.90	16.61	01.81
20	369	249	350	.675	19	0.81	28.86	02.00	35.43	1.14	16.86	15.71
21	398	188	356	.472	37	1.52	47.19	04.77	32.86	1.40	11.23	02.53
22	362	326	345	.900	01	0.87	05.51	00.87	63.48	0.58	04.64	24.93
23	363	291	354	.801	02	0.85	17.80	03.11	65.54	1.13	08.47	03.95
24	392	359	377	.916	01	1.43	04.77	01.33	61.80	3.98	13.79	14.32
25	330	323	326	.978	04	0.37	00.92	01.53	51.23	2.76	23.01	20.55
26	331	297	315	.897	06	1.14	05.71	01.27	38.41	2.86	40.00	11.75
27	418	398	416	.952	02	1.30	04.33	01.20	59.61	1.92	13.70	19.23
28	429	370	420	.862	09	1.71	11.90	04.28	49.76	2.14	24.52	07.38
29	436	382	424	.876	11	0.99	09.90	02.36	52.12	1.89	13.68	20.05
30	397	289	385	.780	03	1.40	24.93	04.41	49.87	0.52	11.69	08.57
32	399	356	397	.892	00	2.87	10.33	02.77	45.84	1.51	14.61	24.93
33	403	312	397	.774	06	0.60	21.41	02.77	50.12	2.52	20.91	02.27
34	404	296	395	.733	09	1.52	25.06	03.29	42.02	1.77	16.20	11.64
35	421	381	414	.905	03	1.01	07.97	02.17	57.73	3.14	18.84	10.14
36	415	346	371	.834	25	1.62	06.74	01.89	53.10	2.69	18.87	16.71
37	421	326	374	.774	47	1.93	12.83	02.67	56.15	1.07	07.22	20.05
38	405	286	382	.706	23	3.14	25.13	06.02	37.70	2.09	14.14	14.92
39	426	378	405	.887	21	1.78	06.67	02.96	63.95	1.48	16.30	08.64
40	413	220	348	.533	60	2.93	36.78	08.91	41.09	1.72	04.60	06.90

List of variables set out in Table A-5

Var. 1) % slow wave sleep
Var. 2) REM latency
Var. 3) Number of REM periods
Var. 4) Average REM period length

Table A-5. EEG variables from 39 older males. (first night only).

ID.#	Var. 1	Var. 2	Var. 3	Var. 4
1	15.89	192	2	21.0
2	10.52	186	2	19.5
3	00.00	242	0	00.0
4	13.59	164	3	22.7
5	26.87	089	3	19.0
6	22.36	137	3	26.0
7	00.00	276	0	00.0
8	23.48	089	4	19.5
9	12.76	100	4	19.0
10	11.95	077	4	24.7
11	24.91	090	3	23.0
12	13.44	091	4	17.0
13	14.34	350	0	00.0
14	15.60	137	3	15.0
15	20.93	288	2	14.0
16	15.03	074	5	16.0
17	04.98	114	4	10.5
18	11.06	363	0	00.0
19	18.35	256	2	03.0
20	25.30	090	3	18.3
21	23.94	179	2	04.5
22	05.52	107	3	28.7
23	11.68	167	1	14.0
24	18.66	084	3	18.0
25	26.01	118	5	13.4
26	45.45	039	5	07.4
27	16.33	109	3	26.7
28	30.27	208	2	15.5
29	17.28	257	2	42.5
30	16.26	159	2	16.5
32	17.98	001	5	19.8
33	23.42	162	1	09.0
34	23.99	194	2	23.0
35	23.88	132	4	10.5
36	23.12	101	6	10.3
37	09.51	227	3	25.0
38	21.68	252	2	28.5
39	19.05	104	3	11.7
40	10.00	280	1	24.0

List of variables set out in Table A-6.

Var. 1) WAIS-R Full Scale IQ
Var. 2) WAIS-R Performance IQ
Var. 3) WAIS-R Verbal IQ
Var. 4) Wechsler Memory Scale - Paired associates score
Var. 5) Verbal fluency (number of words produced)
Var. 6) Wisconsin Card Sort (number of perseverations)
Var. 7) Remote memory questionnaire (# correct)
Var. 8) Spatial recognition test (# correct)
Var. 9) Hooper
Var.10) Finger tapping - right hand
Var.11) Finger tapping - left hand
Var.12) Digit span (age-corrected scale score)

Table A-6. Neuropsychological variables from 39 older males.

ID.#	1	2	3	4	5	6	7	8	9	10	11	12
1	117	118	115	18.0	43	19	20	08	22.5	42	42	14
2	116	124	109	16.0	68	14	18	08	20.5	49	46	12
3	098	087	106	09.5	47	40	26	08	22.0	44	48	11
4	130	136	121	11.5	44	00	41	09	27.0	54	52	12
5	117	112	118	15.0	39	14	29	06	27.0	41	37	11
6	126	121	126	10.5	36	03	34	06	27.0	51	46	13
7	115	103	120	19.0	39	04	28	07	25.0	45	39	10
8	109	106	108	20.0	26	16	19	07	22.5	51	43	11
9	118	105	124	14.5	51	25	23	09	22.5	33	35	12
10	102	103	101	11.5	27	06	14	06	24.0	35	37	11
11	094	098	093	14.5	38	23	26	07	21.5	47	42	07
12	130	126	130	13.0	35	02	28	07	23.0	48	45	12
13	125	122	123	11.0	32	06	24	09	23.5	46	41	14
14	125	121	124	15.0	49	06	43	06	26.5	45	42	12
15	117	111	119	14.5	37	18	31	09	28.0	32	36	10
16	142	138	139	18.0	34	05	37	06	30.0	48	41	14
17	114	110	115	09.0	50	24	30	08	26.0	44	38	10
18	100	103	098	14.0	44	07	37	08	22.0	48	45	11
19	123	112	127	11.5	62	13	27	08	23.5	37	40	12
20	115	107	117	17.5	56	15	35	08	20.5	37	45	14
21	096	088	105	16.0	21	18	35	08	24.5	41	43	08
22	103	111	097	09.5	39	10	31	07	26.5	48	47	11
23	077	071	082	05.5	16	24	10	05	09.5	18	18	03
24	098	106	093	11.0	36	14	26	09	23.5	38	40	09
25	092	087	096	09.0	51	28	13	07	18.5	40	36	11
26	141	132	138	15.0	31	03	40	06	30.0	41	35	15
27	113	115	109	19.0	30	02	40	07	26.5	55	48	08
28	133	130	127	17.0	48	10	41	07	27.5	49	45	14
29	139	136	131	19.0	52	11	37	08	26.5	43	45	14
30	111	110	110	15.5	33	21	36	09	25.0	50	49	12
32	100	108	096	12.5	19	19	14	07	20.5	41	43	09
33	096	092	100	17.0	26	03	13	09	26.0	53	40	11
34	108	105	107	11.0	27	26	18	06	16.5	36	37	10
35	129	131	122	12.0	60	00	31	08	29.5	45	42	12
36	106	107	104	09.0	34	31	17	05	25.5	26	27	12
37	122	132	113	15.5	47	31	21	07	26.0	41	36	09
38	097	107	093	10.0	23	11	31	06	24.5	21	23	07
39	128	119	130	13.0	70	02	44	08	26.0	36	40	14
40	118	117	115	11.0	49	20	33	07	24.5	44	40	17

List of variables set out in Table A-7.

Var. 1) Wechsler Memory Scale - Immediate recall of stories
Var. 2) Wechsler Memory Scale - Delayed recall of stories
Var. 3) Wechsler Memory Scale - Immediate recall of figures
Var. 4) Wechsler Memory Scale - Delayed recall of figures
Var. 5) Rey-Osterrieth - immediate recall
Var. 6) Rey-Osterrieth - delayed recall
Var. 7) California Verbal Learning Test - immediate recall
Var. 8) California Verbal Learning Test - #forgotten

Table A-7. Neuropsychological variables from 39 older males.

ID.#	1	2	3	4	5	6	7	8
1	15.0	14.0	07	02	09	05	60	0
2	15.0	12.0	11	10	09	11	66	0
3	14.5	08.0	04	04	06	07	47	0
4	21.0	16.5	08	08	16	15	42	0
5	17.5	12.0	12	09	12	11	40	1
6	20.5	15.5	14	11	15	14	46	0
7	18.5	18.0	08	08	15	17	67	0
8	20.5	14.5	11	08	18	18	54	0
9	18.5	15.5	09	09	06	07	44	2
10	07.5	05.0	09	09	10	10	42	0
11	13.5	09.5	08	06	08	06	36	1
12	18.0	14.5	14	14	15	16	60	0
13	19.0	00.0	10	07	11	11	35	0
14	14.0	11.0	09	09	14	13	50	0
15	18.5	13.5	09	06	11	10	42	0
16	24.0	19.5	12	11	13	15	61	0
17	16.0	06.0	13	14	14	14	36	2
18	19.0	14.0	10	08	12	12	42	0
19	13.5	07.5	06	00	13	12	28	0
20	26.0	19.5	10	07	09	07	63	0
21	11.5	12.5	07	06	11	10	54	1
22	13.5	10.5	06	05	08	09	30	1
23	15.0	04.0	00	00	05	04	22	2
24	17.0	15.5	14	09	13	13	40	0
25	14.5	08.5	06	02	07	04	35	4
26	22.0	16.0	14	14	17	17	55	2
27	19.0	19.0	12	12	16	15	58	1
28	24.5	24.0	14	14	17	17	41	0
29	21.0	13.5	14	14	14	13	51	1
30	22.0	19.0	12	12	15	15	59	0
32	18.5	12.5	06	05	12	10	32	1
33	27.0	23.0	09	09	11	11	63	0
34	16.5	08.0	07	07	11	10	39	0
35	14.5	08.5	13	11	12	12	61	0
36	06.5	00.0	04	02	05	04	32	3
37	14.5	11.5	14	14	15	15	51	0
38	16.5	13.0	08	07	07	02	31	1
39	23.5	09.5	10	04	04	05	34	0
40	09.5	03.0	06	06	07	07	45	0

List of variables set out in Table A-8.

Var. 1) Apnea Index
Var. 2) Hypopnea Index
Var. 3) Apnea + Hypopnea Index
Var. 4) Mean High Saturation
Var. 5) Mean Low Saturation
Var. 6) Average saturation change: apneas
Var. 7) Average saturation change: hypopneas
Var. 8) Average saturation change: apneas + hypopneas
Var. 9) Number of desaturations $\geq 4\%$/hr.
Var.10) Number of desaturations $\geq 7\%$/hr.

Table A-8. Respiratory variables from 39 older males.

ID	1	2	3	4	5	6	7	8	9	10
1	00.88	00.00	00.88	92.83	91.00	02.83	00.00	02.83	01.18	00.00
2	11.57	09.52	21.08	94.61	89.27	06.29	11.86	08.80	36.75	13.62
3	01.53	36.22	37.75	94.56	86.19	10.17	09.39	09.42	84.69	37.75
4	02.54	00.32	02.86	96.42	94.10	03.94	07.50	04.33	08.25	00.32
5	02.81	00.59	03.40	94.30	92.69	06.21	08.25	06.56	09.45	01.48
6	00.00	00.00	00.00	94.72	93.79	00.00	00.00	00.00	00.00	00.00
7	01.65	00.55	02.20	93.62	91.60	04.83	07.00	05.37	07.16	00.55
8	00.00	00.14	00.14	95.08	93.87	00.00	09.00	09.00	01.25	00.14
9	00.00	00.00	00.00	93.97	92.70	00.00	00.00	00.00	01.10	00.00
10	00.00	00.00	00.00	95.05	94.12	00.00	00.00	00.00	00.90	00.00
11	00.90	00.00	00.90	95.85	94.62	04.20	00.00	04.20	01.61	00.18
12	01.66	00.00	01.66	96.22	95.42	06.73	00.00	06.73	01.66	00.75
13	12.26	18.96	31.23	95.97	89.35	07.22	10.40	09.15	52.87	24.52
14	00.00	00.00	00.00	94.90	94.00	00.00	00.00	00.00	01.47	00.00
15	00.00	00.00	00.00	96.00	95.33	00.00	00.00	00.00	00.00	00.00
16	00.00	00.00	00.00	95.16	94.00	00.00	00.00	00.00	01.45	00.00
17	01.29	00.14	01.44	94.45	93.28	04.33	07.00	04.60	02.59	00.14
18	00.00	00.00	00.00	94.22	92.11	00.00	00.00	00.00	01.53	00.00
19	00.18	00.72	00.90	94.93	94.02	03.00	07.25	06.40	01.63	00.72
20	00.34	00.51	00.86	93.57	92.42	10.00	08.00	08.88	03.77	00.86
21	03.20	00.00	03.20	94.93	94.36	01.89	00.00	01.89	00.17	00.00
22	02.78	00.87	03.65	93.24	91.79	11.37	08.60	10.71	05.04	03.30
23	01.69	11.69	13.39	93.40	88.92	09.50	08.45	08.58	28.47	12.88
24	06.53	03.98	10.51	94.31	91.28	09.76	08.76	09.38	20.22	08.76
25	00.00	00.37	00.37	94.94	93.65	00.00	08.00	08.00	00.92	00.37
26	00.00	00.38	00.38	95.00	93.86	00.00	07.50	07.50	02.28	00.38
27	01.30	00.00	01.30	95.29	93.54	03.44	00.00	03.44	05.48	00.00
28	00.00	00.00	00.00	94.34	93.47	00.00	00.00	00.00	00.00	00.00
29	02.54	00.14	02.69	94.99	93.87	02.94	08.00	03.21	05.94	00.14
30	11.53	01.87	13.39	93.27	89.74	12.04	10.92	11.88	15.42	12.77
32	06.65	00.75	07.40	96.29	94.51	05.64	08.40	05.92	09.67	02.72
33	01.66	12.84	14.50	95.90	91.19	14.45	10.49	10.95	21.60	14.50
34	00.30	00.00	00.30	95.72	94.99	01.50	00.00	01.50	00.30	00.00
35	02.17	00.14	02.32	95.40	94.37	03.67	08.00	03.94	01.59	00.29
36	00.00	00.00	00.00	95.58	94.60	00.00	00.00	00.00	00.32	00.00
37	00.96	00.32	01.28	94.76	94.01	05.17	07.50	05.75	02.09	00.64
38	01.25	00.00	01.25	95.19	94.80	01.50	00.00	01.50	00.31	00.00
39	03.85	00.59	04.44	96.45	95.75	05.23	09.25	05.77	03.41	01.78
40	00.17	00.17	00.34	94.63	93.80	04.00	07.00	05.50	02.07	00.17

List of variables set out in Table A-9.

Var. 1) Total seconds in desaturations ≥4%/hr.
Var. 2) Average duration of saturation change: apneas
Var. 3) Average duration of saturation change: hypopneas
Var. 4) Severity rating
Var. 5) Total seconds in desaturations ≥10%/hr.

Table A-9. Respiratory variables from 39 older males.

ID.#	Var. 1	Var. 2	Var. 3	Var. 4	Var. 5
1	0029.12	16.83	00.00	0042.0	000.00
2	0942.22	22.73	32.90	5068.9	242.65
3	1689.51	22.20	23.03	8180.7	439.69
4	0184.82	20.95	32.75	0275.4	000.00
5	0278.39	29.76	32.35	0673.3	005.49
6	0000.00	00.00	00.00	0000.0	000.00
7	0173.41	23.30	28.50	0291.1	000.00
8	0033.39	00.00	70.00	0087.5	000.00
9	0019.14	00.00	00.00	0000.0	000.00
10	0022.11	00.00	00.00	0000.0	000.00
11	0038.53	17.80	00.00	0067.1	000.00
12	0065.83	33.36	00.00	0373.1	024.35
13	1302.32	23.60	28.20	7542.1	380.17
14	0049.40	00.00	00.00	0000.0	000.00
15	0000.00	00.00	00.00	0000.0	000.00
16	0049.40	00.00	00.00	0000.0	000.00
17	0056.98	18.93	30.00	0132.6	000.00
18	0039.83	00.00	00.00	0000.0	000.00
19	0050.76	16.00	38.65	0197.8	000.00
20	0098.64	23.80	22.00	0173.0	008.16
21	0003.14	14.55	00.00	0088.1	000.00
22	0145.46	29.73	35.56	1217.2	066.19
23	0773.73	26.70	28.61	3288.0	079.83
24	0649.27	29.09	42.91	3384.1	143.84
25	0043.44	00.00	55.75	0164.2	000.00
26	0103.35	00.00	68.00	0194.2	000.00
27	0143.10	21.49	00.00	0096.0	000.00
28	0000.00	00.00	00.00	0000.0	000.00
29	0204.52	25.17	43.00	0225.2	000.00
30	0542.99	34.72	30.00	5420.0	404.52
32	0277.94	28.09	32.80	1251.9	005.89
33	0693.65	37.27	35.34	5647.0	331.42
34	0005.93	15.50	00.00	0007.1	000.00
35	0058.84	27.60	34.00	0255.8	006.09
36	0019.25	00.00	00.00	0000.0	000.00
37	0078.17	29.00	77.00	0302.7	007.70
38	0007.85	13.25	00.00	0024.9	000.00
39	0135.85	31.61	44.25	0853.9	053.78
40	0055.52	22.00	23.00	0042.7	000.00

List of variables set out in Tables A-10, A-11.

Var. 1) Time in bed
Var. 2) Pure sleep time
Var. 3) Sleep period time
Var. 4) Sleep efficiency
Var. 5) Sleep latency
Var. 6) Number of awakenings
Var. 7) % stage 0
Var. 8) % stage 1
Var. 9) % stage 2
Var.10) % stage 3
Var.11) % stage 4
Var.12) % stage REM

Table A-10. First night EEG variables from 14 older males.

ID	1	2	3	4	5	6	7	8	9	10	11	12
2	427	380	410	.89	15	1.02	7.31	3.41	70.00	3.17	06.58	09.51
5	413	387	406	.94	07	0.59	4.67	0.98	54.67	2.21	23.39	14.03
24	392	359	377	.92	01	1.43	4.77	1.33	61.80	3.98	13.79	14.32
23	363	291	354	.80	02	0.85	17.80	3.11	65.54	1.13	08.47	03.95
30	397	289	385	.73	03	1.40	24.93	4.41	49.87	0.52	11.69	08.57
33	403	312	397	.77	06	0.60	21.41	2.77	50.12	2.52	20.91	02.27
39	426	378	405	.89	21	1.78	06.67	2.96	63.95	1.48	16.30	08.64
4	382	353	378	.92	03	1.59	06.61	2.64	60.05	1.05	11.64	17.98
17	427	401	417	.94	10	0.72	03.83	1.43	79.85	1.19	03.59	10.07
29	436	382	424	.88	11	.99	09.90	2.36	52.12	1.89	13.68	20.05
35	421	381	414	.91	03	1.01	07.97	2.17	57.73	3.14	18.84	10.14
36	415	346	371	.83	25	1.62	06.74	1.89	53.10	2.69	18.87	16.71
37	421	326	374	.77	47	1.93	12.83	2.67	56.15	1.07	07.22	20.05
38	405	286	382	.71	23	3.14	25.13	6.02	37.70	2.09	14.14	14.92

Table A-11. Second night EEG variables from 14 older males.

ID	1	2	3	4	5	6	7	8	9	10	11	12
2	431	403	429	.94	02	0.84	06.06	1.86	58.50	2.09	13.51	17.94
5	346	328	342	.95	04	1.05	04.09	0.58	59.35	1.75	23.97	10.23
24	401	393	399	.98	02	0.45	01.50	1.00	55.89	2.25	22.56	16.79
23	389	355	381	.91	03	0.47	06.82	1.05	63.52	4.20	24.41	00.00
30	372	353	371	.95	01	1.13	04.85	1.35	68.19	1.62	10.78	13.21
33	409	340	397	.83	08	1.21	14.36	4.28	48.36	2.01	22.67	08.31
39	362	344	359	.95	03	0.84	04.18	1.39	59.61	2.23	15.04	17.55
4	435	422	432	.97	02	0.97	02.31	0.92	56.94	4.17	18.98	16.67
17	465	446	460	.96	05	0.91	03.04	1.95	67.60	1.08	08.69	17.60
29	453	400	448	.88	05	2.54	10.71	1.12	57.81	2.45	11.16	16.74
35	422	348	381	.83	10	2.36	08.66	3.94	53.02	3.15	12.60	18.63
36	394	364	391	.92	03	1.23	06.90	2.05	53.96	1.02	11.00	25.06
37	400	327	371	.82	22	2.75	12.13	2.96	54.99	2.16	14.55	13.21
38	395	318	359	.81	19	2.17	11.42	3.06	44.01	3.62	20.05	17.83

List of variables set out in Tables A-12, A-13.

Var. 1) % slow wave sleep
Var. 2) REM latency
Var. 3) Number of REM periods
Var. 4) Average REM period length

Table A-12. First night EEG variables from 14 older males.

ID.#	Var. 1	Var. 2	Var. 3	Var. 4
2	10.52	186	2	19.5
5	26.87	089	3	19.0
24	18.66	084	3	18.0
23	11.68	167	1	14.0
30	16.26	159	2	16.5
33	23.42	162	1	09.0
39	19.05	104	3	11.7
4	13.59	164	3	22.7
17	04.98	114	4	10.5
29	17.28	257	2	42.5
35	23.88	132	4	10.5
36	23.12	101	6	10.3
37	09.51	227	3	25.0
38	21.68	252	2	28.5

Table A-13. Second night EEG variables from 14 older males.

ID.#	Var. 1	Var. 2	Var. 3	Var. 4
2	16.62	093	3	25.67
5	26.82	135	2	17.50
24	25.19	066	4	16.75
23	30.70	389	0	00.00
30	13.03	233	2	24.50
33	28.82	114	3	11.00
39	18.02	043	4	15.75
4	23.69	079	4	18.00
17	10.08	076	5	16.20
29	15.25	185	3	25.00
35	17.24	053	7	10.14
36	12.91	053	4	24.50
37	18.96	110	3	16.33
38	26.73	180	2	32.00

List of variables set out in Tables A-14, A-15.

Var. 1) Apnea Index
Var. 2) Hypopnea Index
Var. 3) Apnea + Hypopnea Index
Var. 4) Mean High Saturation
Var. 5) Mean Low Saturation
Var. 6) Average saturation change: apneas
Var. 7) Average saturation change: hypopneas
Var. 8) Average saturation change: apneas + hypopneas
Var. 9) Number of desaturations ≥4%/hr.

Table A-14. First night respiratory variables from 14 older males.

ID	1	2	3	4	5	6	7	8	9
2	11.57	09.52	21.08	94.61	89.27	06.29	11.86	08.80	36.75
5	02.81	00.59	03.40	94.30	92.69	06.21	08.25	06.56	09.45
24	06.53	03.98	10.51	94.31	91.28	09.76	08.76	09.38	20.22
23	01.69	11.69	13.39	93.40	88.92	09.50	08.45	08.58	28.47
30	11.53	01.87	13.39	93.27	89.74	12.04	10.92	11.88	15.42
33	01.66	12.84	14.50	95.90	91.89	14.45	10.49	10.95	21.60
39	03.85	00.59	04.44	96.45	95.75	05.23	09.25	05.77	03.41
4	02.54	00.32	02.86	96.42	94.10	03.94	07.50	04.33	08.25
17	01.29	00.14	01.44	94.45	93.28	04.33	07.00	04.60	02.59
29	02.54	00.14	02.69	94.99	93.87	02.94	08.00	03.21	05.94
35	02.17	00.14	02.32	95.40	94.37	03.67	08.00	03.94	01.59
36	00.00	00.00	00.00	95.58	94.60	00.00	00.00	00.00	00.32
37	00.96	00.32	01.28	94.76	94.01	05.17	07.50	05.75	02.09
38	01.25	00.00	01.25	95.19	94.80	01.50	00.00	01.50	00.31

Table A-15. Second night respiratory variables from 14 older men.

ID.#	1	2	3	4	5	6	7	8	9
2	6.71	06.71	13.42	94.91	90.79	07.27	09.52	08.39	28.81
5	03.51	02.81	06.31	94.13	92.23	09.70	09.50	09.61	11.23
24	00.60	01.95	02.56	95.35	93.14	10.50	08.38	08.88	10.37
23	00.00	04.86	04.86	94.39	91.32	00.00	08.53	08.53	19.71
30	16.99	10.03	27.02	94.61	88.08	12.45	11.43	12.07	29.45
33	09.11	20.44	29.55	93.98	81.63	22.97	15.26	17.64	31.11
39	01.84	00.00	01.84	95.72	95.41	02.64	00.00	02.64	00.33
4	03.19	00.14	03.33	94.82	93.25	03.09	07.00	03.25	02.78
17	06.52	01.04	07.56	94.55	92.56	04.58	07.50	04.98	14.47
29	06.42	00.40	06.83	94.48	92.63	03.85	07.00	04.04	11.91
35	01.43	00.00	01.43	95.59	94.77	03.78	00.00	03.78	01.43
36	00.00	00.00	00.00	96.36	95.46	00.00	00.00	00.00	00.00
37	00.65	00.32	00.97	94.86	94.16	02.75	07.00	04.17	01.62
38	01.50	00.00	01.50	95.64	95.28	02.00	00.00	02.00	00.33

List of variables set out in Tables A-16, A-17.

Var. 1) Total seconds in desaturations ≥4%/hr.
Var. 2) Average duration of saturation change: apneas
Var. 3) Average duration of saturation change: hypopneas
Var. 4) Severity rating
Var. 5) Total seconds in desaturations ≥10%/hr.
Var. 6) Number of Desaturations ≥7%
Var. 7) Number of Desaturations ≥10%
Var. 8) Total seconds in Apneas + Hypopneas

Table A-16. First night respiratory variables from 14 older males.

ID	1	2	3	4	5	6	7	8
2	942.22	22.73	32.90	5068.9	242.65	13.62	06.59	576.02
5	278.39	29.76	32.35	0275.4	000.00	01.48	00.15	102.64
24	649.27	29.09	42.91	3384.1	143.84	08.76	04.14	360.78
23	773.73	26.70	28.61	3288.0	079.83	12.88	02.54	383.22
30	542.99	34.72	30.00	5420.0	404.52	12.77	11.37	456.23
33	693.65	37.27	35.34	5647.0	331.42	14.50	08.31	515.71
39	135.85	31.61	44.25	0853.9	053.78	01.78	01.04	148.00
4	184.82	20.95	32.75	0275.4	000.00	00.32	00.00	063.60
17	056.98	18.93	30.00	0132.6	000.00	00.14	00.00	028.83
29	204.52	25.17	43.00	0225.2	000.00	00.14	00.00	070.15
35	058.84	27.60	34.00	0255.8	006.09	00.29	00.14	064.93
36	019.25	00.00	00.00	0000.0	000.00	00.00	00.00	000.00
37	078.17	29.00	77.00	0302.7	007.70	00.64	00.16	052.65
38	007.85	13.25	00.00	0024.9	000.00	00.00	00.00	016.64

Table A-17. Second night respiratory variables from 14 older males.

ID	1	2	3	4	5	6	7	8
2	817.71	26.62	35.43	3495.02	143.12	09.23	03.78	416.57
5	366.00	32.98	34.43	2040.97	109.26	06.31	02.98	212.38
24	299.83	29.60	34.96	0765.10	020.81	02.25	00.60	086.16
23	439.14	00.00	21.82	0904.18	023.14	04.86	00.86	106.00
30	1032.69	36.14	34.26	11560.28	886.73	26.86	24.11	957.77
33	1131.78	38.15	36.64	19345.26	985.11	29.55	26.89	1096.67
39	010.70	25.18	00.00	0122.28	000.00	00.17	00.00	046.32
4	071.46	20.39	27.00	0223.89	000.00	00.14	00.00	068.89
17	316.52	19.79	27.27	0784.00	000.00	01.56	00.00	157.43
29	375.63	27.02	38.00	0763.11	000.00	00.80	00.00	188.89
35	045.87	25.22	00.00	0136.19	000.00	00.00	00.00	036.03
36	000.00	00.00	00.00	0000.00	000.00	00.00	00.00	000.00
37	045.79	18.50	32.50	0093.78	000.00	00.32	00.00	022.49
38	006.52	15.11	00.00	0045.48	000.00	00.00	00.00	022.74

REFERENCES

Agnew, H.W., & Webb, W.B. (1972). Sleep stage scoring. JSAS Catalog of Selected Documents in Psychology. Manuscript #293.

Agnew, H., Webb, W., & Williams, R. (1966). The first night effect: An EEG study of sleep. Psychophysiology, 2, 263-266.

Ancoli-Israel, S., Kripke, D., Mason, W., & Messin, S. (1981). Sleep apnea and nocturnal myoclonus in a senior population. Sleep, 4, 349-358.

Ancoli-Israel, S., Kripke, D., Mason, W., & Kaplan, O. (1985). Sleep apnea and periodic movements in an aging sample. Journal of Gerontology, 40, 419-425.

Ancoli-Israel, S., Kripke, D., Mason, W., Gabriel, S., & Kaplan, O. (1986). Sleep apnea and PMS in a randomly selected elderly population: Final prevalence results. Sleep Research, 15, 101.

Association of Sleep Disorder Centers (1979). Diagnostic classification of sleep and arousal disorders. Sleep, 2, 1-137.

Benton, A. (1973). The measurement of aphasic disorders. In A. Velasquez. Aspectos patologicos del lenguage. Lima: Centro Neuropsicologico.

Berg, I. (1948). A simple objective technique for measuring flexibility in thinking. Journal of General Psychology, 39, 15-22.

Berry, D. (1986). Sleep apnea activity and its concomitants in a subclinical population (Doctoral Dissertation, University of Florida, 1985). Dissertation Abstracts International, 46, 3765A.

Berry, D., Webb, W., Block, A.J., Bauer, R., & Switzer, D. (1986a). Nocturnal hypoxia and neuropsychological variables. Journal of Clinical and Experimental Neuropsychology, 8, 229-238.

Berry, D., Webb, W., Block, A.J., & Switzer, D. (1986b). Sleep-disordered breathing and its concomitants in a sub-clinical population. Sleep, 9, 478-483.

Bixler, E., Kales, A., Cadieux, R., Vela-Bueno, A., Jacoby, J. & Soldatos, C. (1985). Sleep apneic activity in older healthy subjects. Journal of Applied Physiology, 58, 1597-1601.

Bixler, E., Kales, A., Soldatos, C., Vela-Bueno, A., Jacoby, J. & Scarone, S. (1982). Sleep apneic activity in a normal population. Research Communications in Chemical Pathology and Pharmacology, 36, 141-152.

Bliwise, D., Carey, E., & Dement, W. (1983). Nightly variation in sleep-related respiratory disturbance in older adults. Experimental Aging Research, 9, 77-81.

Block, A.J., Boysen, P., Wynne, J., & Hunt, L. (1979). Sleep apnea, hypopnea and oxygen desaturation in normal subjects. The New England Journal of Medicine, 300, 513-517.

Block, A.J., Wynne, J., & Boysen, P. (1980). Sleep-disordered breathing and nocturnal oxygen desaturation in postmenopausal women. The American Journal of Medicine, 69, 75-79.

Block, A.J., Wynne, J., Boysen, P., Lindsey, S., Martin, C., & Cantor, B. (1981). Menopause, medroxyprogesterone and breathing during sleep. The American Journal of Medicine, 70, 506-510.

Bonnet, M.H. (1985). Effect of sleep disruption on sleep, performance, and mood. Sleep, 8, 11-19.

Bonnet, M.H. (1986). Performance and sleepiness as a function of frequency and placement of sleep disruption. Psychophysiology, 23, 263-270.

Bonnet, M.H. (1987). Sleep restoration as a function of periodic awakening, movement, or electroencephalographic change. Sleep, 10, 364-373.

Bonnet, M.H., Downey, R., Wilms, D., & Dexter, J. (1986). Sleep continuity theory as a predictor of EDS in sleep apneics. Sleep Research, 15, 105.

Broadman, K., Furdman, A., Lorge, I., Wolf, H., & Broadbent, T. (1949). The Cornell Medical Index. Journal of the American Medical Association, 140, 530-534.

Carskadon, M., & Dement, W. (1981) Respiration during sleep in the aged human. Journal of Gerontology, 36, 420-423.

Carskadon, M., van den Hoed, J., & Dement, W. (1980). Insomnia and sleep disturbances in the elderly. Journal of Geriatric Psychiatry, 13, 135-151.

Coleman, R., Miles, L., Guilleminalult, C., Zarcone, V., van den Hoed, J., & Dement, W. (1981). Sleep-wake disorders in the elderly: A polysomnographic analysis. Journal of the American Geriatrics Society, 29, 289- 296.

Coverdale, S.G.M., Read, D., Woolcock, A., & Schoeffel, R. (1980). The importance of suspecting sleep apnea as a common cause of excessive daytime sleepiness. Australian and New Zealand Journal of Medicine, 10, 284-288.

Dement, W., Carskadon, M., & Richardson, G. (1978). Excessive daytime sleepiness in the sleep apnea syndrome. In C. Guilleminault & W. Dement (eds), Sleep Apnea Syndromes. New York: Alan R. Liss Inc.

Dolly, F., & Block, A. (1982). Effect of flurazepam on sleep disordered breathing in asymptomatic subjects. American Journal of Medicine, 73, 239-243.

Findley, L., Barth, J., Powers, C., Wilhoit, S., Boyd, D., & Suratt, P. (1986). Cognitive impairment in patients with obstructive sleep apnea and assoxiated hypoxemia. Chest, 90, 686-690.

Fujita, S., Zorick, F., Koshorek, G., Wittig, R., Conway, W., & Roth, T. (1981). Treatment of upper airway sleep apnea with UPP: Recent experience. Sleep Research, 10, 197.

Garay, S., Rapoport, D., Sorkin, B., Epstein, H., Feinberg, I., & Goldring, R. (1981). Regulation of ventilation in the obstructive sleep apnea syndrome. American Review of Respiratory Disease, 124, 451-457.

Gerard, P., Collins, K., Dove, C., & Exton-Smith, A. (1978) Subjective characteristics of sleep in the elderly. Age and Ageing, 7(Supplement), 55-59.

Gibson, G., Pulsinelli, W., Blass, J., & Duffy, T. (1981). Brain dysfunction in mild to moderate hypoxia. The American Journal of Medicine, 70, 1247-1254.

Grant, I., Heaton, R., McSweeny, A.J., Adams, K., & Timms, R. (1982). Neuropsychologic findings in hypoxemic chronic obstructive pulmonary disease. Archives of Internal Medicine, 142, 1470-1476.

Greenberg, G., Watson, R., & Deptula, D. (1987). Neuropsychological dysfunction in sleep apnea. Sleep, 10, 254-262.

Guilleminault, C., Motta, J., Mihm, F., & Melvin, K. (1986). Obstructive sleep apnea and cardiac index. Chest, 89, 331-334.

Guilleminault, C., Tilkian, A., & Dement, W. (1976). The sleep apnea syndromes. Annual Review of Medicine, 27, 465-484.

Guilleminault, C., van den Hoed, J., & Mitler, M. (1978). Clinical overview of the sleep apnea syndromes. In C. Guilleminault and W. Dement (eds), Sleep Apnea Syndromes. New York: Alan R. Liss Inc.

Hartmann, E. (1968). Adaptation to the sleep laboratory and placebo effect. Psychophysiology, 4, 389.

Hartse, K., Zorick, F., Roth, T., Kaffeman, M., & Moyles, T. (1980). Daytime sleep tendency in normal, insomniac, and somnolent populations. Sleep Research, 9, 204.

Hesla, P., Nay, K., Kiel, M., Mendez, A., Coolidge, T., Norman, S., & Cohn, M. (1985). Quantitative changes in sleep parameters in patients with obstructive sleep apnea. Sleep Research, 14, 163.

Hoch, C., Reynolds, C., Kupfer, D., Houck, P., Berman, S., & Stack, J. (1986). Sleep-disordered breathing in normal and pathologic aging. Journal of Clinical Psychiatry, 47, 499-503.

Hoddes, E., Zarcone, V., Smythe, H., Phillips, R., & Dement, W. (1973). Quantification of sleepiness: New approach. Psychophysiology, 10, 431-436.

Holzer, B., Pressman, M., & Fry, J. (1985). REM sleep and slow wave sleep (SWS) rebound with nasal CPAP treatment of sleep apnea. Sleep Research, 14, 165

Hooper, H. (1958). The Hooper Visual Organization Test: Manual. Los Angeles: Western Psychological Services.

Issa, F., & Sullivan, C. (1986). The immediate effects of nasal continuous positive airway pressure treatment on sleep pattern in patients with obstructive sleep apnea syndrome. Electroencephalography and Clinical Neurophysiology, 63, 10-17.

Johnson, L. (1982). Sleep deprivation and performance. In W. Webb (ed.), Biological Rhythms, Sleep, and Performance. New York: Wiley.

Kales, A., Bixler, E., Soldatos, C., Vela-Bueno, A., Caldwell, A., & Cadieux, R. (1982). Insomnia: The role of sleep apnea and nocturnal myoclonus. Psychosomatics, 23, 589-600.

Kales, A., Cadieux, R., Bixler, E., Soldatos, C., Vela-Bueno, A., Misoul, C., & Locke, T. (1985a). Severe obstructive sleep apnea--I.: Onset, clinical course, and characteristics. Journal of Chronic Diseases, 38, 419-425.

Kales, A., Caldwell, A., Cadieux, R., Vela-Bueno, A., Ruch, L., & Mayes, S. (1985b). Severe obstructive sleep apnea--II: Associated psychopathology and psychosocial consequences. Journal of Chronic Diseases, 38, 427- 434.

Klonoff, H., Fleetham, J., Taylor, R., & Clark, C. (1987). Treatment outcome of obstructive sleep apnea. Journal of Nervous and Mental Disease, 175, 208-212.

Knight, H., Millman, R., Gur. R., Saykin, A.K, Soherty, J., & Pack, A. (1987). Clinical significance of sleep apnea in the elderly. American Review of Respiratory Disease, 136, 845-850.

Kramer, M., & Silva, C. (1986). Night to night variability of apnea. Sleep Research, 15, 138.

Krieger, J., Turlot, A., Mangin, P., & Kurtz, D. (1983). Breathing during sleep in normal young and elderly subjects: Hypopneas, apneas, and correlated factors. Sleep, 6, 108-120.

Krop, H., Block, A.J., & Cohen, E. (1973). Neuropsychologic effects of continuous oxygen therapy in chronic obstructive pulmonary disease. Chest, 64, 317-322.

Kupfer, D., Weiss, B., Detre, T., & Foster, G. (1974). First night effect revisited: A clinical note. Journal of Nervous and Mental Disease, 159, 205-209.

Lavie, P. (1983). Incidence of sleep apnea in a presumably healthy working population: A significant relationship with excessive daytime sleepiness. Sleep, 6, 312-318.

Littner, M., & McGinty, D. (1985). Asymptomatic disordered breathing during sleep in older persons. Archives of Internal Medicine, 145, 233-234.

McGinty, D., Littner, M., Beahm, E., Ruiz-Primo, E., Young, E., & Sowers, J. (1982). Sleep related breathing disorders in older men: A search for underlying mechanisms. Neurobiology of Aging, 3, 337-350.

Norman, S., Levin, B., & Cohn, M. (1986). Neuropsychological correlates of obstructive sleep apnea syndrome. Sleep Research, 15, 95.

Orr, W. (1986). Sleep apnea, hypoxemia, and cardiac arrhythmias. Chest, 89, 1-2.

Orr, W., Martin, R., Imes, N., Rogers, R., & Stahl, M. (1979). Hypersomnolent and nonhypersomnolent patients with upper airway obstruction during sleep. Chest, 75, 418-422.

Osterrieth, P. (1944). Le test de copie d'une figure complexe. Archives de Psychologie, 30, 205-256.

Prigatano, G., Parsons, O., Levin, D., Wright, E., Hawryluk, G. (1983). Neuropsychological test performance in mildly hypoxemic patients with chronic obstructive pulmonary disease. Journal of Consulting and Clinical Psychology, 51, 108-116.

Reynolds, C., Coble, P., Black, R., Holzer, B., Carroll, R., & Kupfer, D. (1980). Sleep disturbances in a series of elderly patients: Polysomnographic findings. Journal of the American Geriatrics Society, 28, 164-170.

Reynolds, C., Kupfer, D., Taska, L., Hoch, C., Sewitch, D., Restifo, K., Spiker, D., Zimmer, B., Marin, R., Nelson, J., Martin, D., & Morycz, R. (1985). Sleep apnea in Alzheimer's dementia: Correlation with mental deterioration. Journal of Clinical Psychiatry, 46, 257-261.

Roth, T., Hartse, K., Zorick, F., & Conway, W. (1980). Multiple naps and the evaluation of daytime sleepiness in patients with upper airway sleep apnea. Sleep, 3, 425-439.

Russell, E. (1975). A multiple scoring method for assessment of complex memory functions. Journal of Consulting and Clinical Psychology, 43, 800-809.

Schmidt, H., & Kaelbling, R. (1971). The differential laboratory adaptation of sleep parameters. Biological Psychiatry, 3, 33-45.

Schroeder, J., Motta, J., & Guilleminault, C. (1978). Hemodynamic studies in sleep apnea. In C. Guilleminault & W. Dement (eds.), Sleep Apnea Syndrome. New York: Alan R. Liss Inc.

Shepard, J., Garrison, M.k, Grither, D., & Dolan, G. (1985). Relationship of ventricular ectopy to oxyhemoglobin desaturation in patients with obstructive sleep apnea. Chest, 88, 335-340.

Sink, J., Bliwise, D., & Dement, W. (1986). Self-reported excessive daytime somnolence and impaired respiration in sleep. Chest, 90, 177-180.

Smallwood, R., Vitiello, M., Giblin, E., & Prinz, P. (1983). Sleep apnea: Relationship to age, sex, and Alzheimer's dementia. Sleep, 6, 16-22.

Smirne, S., Franceschi, M., Comi, G., & Leder, F. (1980). Sleep apneas in Alzheimer's disease. Sleep Research, 9, 224.

Stepanski, E., Lamphere, J., Badia, P., Zorick, F., & Roth, T. (1984). Sleep fragmentation and daytime sleepiness. Sleep, 7, 18-26.

Sullivan, C., & Issa, F. (1980). Pathophysiological mechanisms in obstructive sleep apnea. Sleep, 3, 235-246.

Tilkian, A., Motta, J., & Guilleminault, C. (1978). Cardiac arrhythmias in sleep apnea. In C. Guilleminault & W. Dement (eds.), Sleep Apnea Syndromes. New York: Alan Liss, Inc.

Timms, R., Shaforenko, R., Hajdukovic, R., & Mitner, M. (1985). Sleep apnea syndrome: Quantitative studies of nighttime measures and daytime alertness. Sleep Research, 14, 222.

Tune, G. (1969). Sleep and wakefulness in 509 normal human adults. British Journal of Medicine and Psychology, 42, 75-80.

Webb, P. (1974). Breathing during sleep. Journal of Applied Physiology, 37, 899-903.

Webb, W. (1982). The measurement and characteristics of sleep in older persons. Neurobiology of Aging, 3, 311-319.

Webb, W., & Campbell, S. (1979). The first night effect revisited with age as a variable. Waking and Sleeping, 3, 319-324.

Webb, W., & Dreblow, L. (1982). A modified method for scoring slow wave sleep of older subjects. Sleep, 5, 195-199.

Wechsler, D. (1945). A standardized memory scale for clinical use. Journal of Psychology, 19, 87-95.

Wechsler, D. (1955). Wechsler Adult Intelligence Scale: Manual. New York: Psychological Corporation.

Weitzman, E., Kahn, E., & Pollak, C. (1980). Quantitative analysis of sleep and sleep states before and after tracheostomy in patients with the hypersomnia sleep apnea syndrome. Sleep, 3, 407-423.

Wittig, R., Romaker, A., Zorick, F., Roehrs, A., Conway, W., & Roth, T. (1984). Night-to-night consistency of apneas during sleep. American Review of Respiratory Disease, 129, 244-246.

Yesavage, J., Bliwise, D., Guilleminault, G., Carskadon, M., & Dement, W. (1985). Preliminary communication: Intellectual deficit and sleep-related respiratory disturbance in the elderly. Sleep, 8, 30-33.

Zepelin, H. (1973). A survey of age differences in sleep patterns and dream recall among well-educated men and women. Sleep Research, 2, 81.

Zorick, F., Roehrs, T., Koshorek, G., Sicklesteel, J., Hartse, K., Wittig, R., & Roth, T. (1982) Patterns of sleepiness in various disorders of excessive daytime sleepiness. Sleep, 5, S165-S174.

Zwillich, C., Devlin, T., White, D., Douglass, N., Weil, J., & Martin, R. (1982) Bradycardia during sleep apnea. Journal of Clinical Investigations, 69, 1286-1292.

BIOGRAPHICAL SKETCH

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Hugh Davis, Chair
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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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